



# **NAVAL POSTGRADUATE SCHOOL**

**MONTEREY, CALIFORNIA**

## **THESIS**

### **QUANTIFYING SLEEP AND PERFORMANCE OF WEST POINT CADETS: A BASELINE STUDY**

by

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June 2004

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**QUANTIFYING SLEEP AND PERFORMANCE OF WEST POINT CADETS: A  
BASELINE STUDY**

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## ABSTRACT

This study reports the initial findings of a four-year longitudinal study undertaken to assess the total amount of sleep received by cadets at the United States Military Academy. Specifically, data on the Class of 2007 were collected and analyzed during the freshman year. Survey data were collected ( $n=1290$ ) on sleep habits prior to the cadets reporting to the Academy. Actigraphy data were collected ( $n=80$ ) during summer military training and during the Fall academic semester. Survey data were analyzed using two different methods to determine total amount of sleep prior to reporting to the Academy ( $\bar{x}=8.5$  hrs,  $s.d.=1.7$  hrs;  $\bar{x}=7.76$  hrs,  $s.d.=1.46$  hrs). Actigraphy data revealed that cadets received much less nighttime sleep (naps not included) during the Fall academic semester than they reported receiving in the 30 days before Cadet Basic Training (total:  $\bar{x}=5.32$  hrs,  $s.d.=35.3$  mins; school nights:  $\bar{x}=4.86$  hrs,  $s.d.=37.4$  mins; non-school nights:  $\bar{x}=6.56$  hrs,  $s.d.=64.4$  mins). Using morningness-eveningness chronotypes, owls and non-owls differed significantly along the following dimensions: cadet attrition ( $z=2.66$ ,  $p=0.0039$ ), fall term academic quality point average ( $t=3.92$ ,  $p<0.001$ ), military program score ( $t=5.169$ ,  $p<0.001$ ), and physical program score ( $t=3.295$ ,  $p=0.001$ ). Suggestions for additional analysis of existing and subsequent data are proposed.

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## EXECUTIVE SUMMARY

Sustained and continuous military operations are a reality, especially in an age with a large focus placed on Military Operations Other Than War (MOOTW). The prevailing military culture encourages senior leaders to appear “superhuman” in their abilities to lead from the front, even on only a few hours of sleep per night. Additionally, they may be as demanding of their subordinates as they are of themselves, and unaware that they are operating with a degraded cognitive function. At the United States Military Academy at West Point, New York, cadets assume a rigorous schedule full of competing demands—military, athletic, and academic.

This study reports the initial findings of a four-year longitudinal study undertaken to assess the total amount of sleep received by cadets at the United States Military Academy. Specifically, data on the Class of 2007 were collected and analyzed during the freshman year. Survey data were collected (n=1290) on sleep habits prior to the cadets reporting to the Academy. Actigraphy data were collected (n=80) during summer military training and during the Fall academic semester. Survey data were analyzed using two different methods to determine total amount of sleep prior to reporting to the Academy ( $\bar{x}$ =8.5 hrs, s.d.=1.7 hrs;  $\bar{x}$ =7.76 hrs, s.d.=1.46 hrs). Actigraphy data revealed that cadets received much less nighttime sleep (naps not included) during the Fall academic semester than they reported receiving in the 30 days before Cadet Basic Training (total:  $\bar{x}$ =5.32 hrs, s.d.=35.3 mins; school nights:  $\bar{x}$ =4.86 hrs, s.d.=37.4 mins; non-school nights:  $\bar{x}$ =6.56 hrs, s.d.=64.4 mins). Using morningness-eveningness chronotypes, owls and non-owls differed significantly along the following dimensions: cadet attrition ( $z=2.66$ ,  $p=0.0039$ ), fall term academic quality point average ( $t=3.92$ ,  $p<0.001$ ), military program score ( $t=5.169$ ,  $p<0.001$ ), and physical program score ( $t=3.295$ ,  $p=0.001$ ). Suggestions for additional analysis of existing and subsequent data are proposed.

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# **I. INTRODUCTION**

## **A. OVERVIEW**

Sustained and continuous military operations are a reality, especially in an age with a large focus placed on Military Operations Other Than War (MOOTW). The prevailing military culture encourages senior leaders to appear “superhuman” in their abilities to lead from the front, even on only a few hours of sleep per night. Additionally, they may be as demanding of their subordinates as they are of themselves, and unaware that they are operating with a degraded cognitive function.

At the United States Military Academy at West Point, New York, cadets assume a rigorous schedule full of competing demands—military, athletic, and academic. However the most recent classes of cadets have many new social distractions such as video games, Internet, cellular telephones, and personal computers with DVD players. Their cadet experience is very different from that of the first class in 1802, and requires a different set of time management skills. These ambitious youths are striving for the same successes as in years past, and sleep may be sacrificed to accommodate increasing time allotted for competing activities. It is certain that cadets today are receiving less than the recommended eight or nine hours of sleep per night. Prolonged sleep deprivation may hinder their chance of thriving in their academic pursuits.

This thesis is part of a four-year longitudinal study designed to assess the sleep hygiene of the cadets of West Point. In Chapter I, the introduction and background are presented. Chapter II is a literature review of the current knowledge about sleep. Chapter III reports the methods used in the collection and analysis of the data while Chapter IV presents results of the analysis. Chapter V contains the discussion of the results and conclusions from the current study and recommendations for future work.

## **B. PROBLEM AND PURPOSE**

To educate, train, and inspire the Corps of cadets so that each graduate is a commissioned leader of character committed to the values of Duty, Honor, Country; professional growth throughout a career as an officer in the United States Army; and a lifetime of selfless service to the nation.<sup>1</sup>

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<sup>1</sup> Mission statement of the United States Military Academy. Taken from the New Cadet Handbook.

This is the mission statement of the United States Military Academy (USMA), memorized by all those who join the Long Gray Line, and the code around which cadet life is designed. In seeming conflict with this purpose is a tendency for cadets to assume more activities than they can handle in the waking day, resulting in decreased time allotted for sleeping. Historically many military members view sleep as “self indulgent” and the cadet or officer deprived of sleep in the interest of duty is revered, even though he may be unknowingly setting himself up for mission failure (Shay, 1998). In his 1998 paper from the Army War College, Shay, M.D., Ph.D., writes, “Practices that *assume* sustained superhuman effort plant the seeds of operational failure.”

Performance degradation is a well-documented consequence of sleep deprivation (Belenky et al., 2003; Van Dongen, Maislin, Mullington, & Dinges, 2003). Anecdotal data indicate that chronic sleep deprivation is a major problem at the Military Service Academies. In order to be able to fully flourish under the education and training at West Point, a cadet needs adequate sleep.

The focus of this study is the entire Class of 2007, and a stratified sample of 80 of those cadets who recorded their sleep activity for four weeks in November and December of 2003. It describes the sleep patterns of West Point cadets thirty days prior to reporting to West Point. Additionally, it compares this reported sleep information to the sleep received by these cadets during a portion of the Fall Academic Semester. It assesses the sleeping patterns of the Corps of Cadets in light of the most current research on sleep and adolescence. Serving as the baseline for a four-year longitudinal study for the West Point cadets of the Class of 2007, the results of this thesis help to lay the foundation for future analysis, including an exploration of the academic consequences of sleep deprivation in West Point cadets. It provides a factual basis for USMA administrative discussion of policy options that may be implemented in order to optimize cadet sleep. It also examines if sleep is a predictor of performance, and explores relationships between sleep and a variety of demographic variables.

### **C. APPROACH**

On the first day of Cadet Basic Training (CBT), the entire Class of 2007 filled out a survey of their sleeping habits to include the Pittsburgh Sleep Quality Index (PSQI), in order to assess the quality of sleep each individual received prior to their reporting to USMA. This pre-CBT survey was administered to establish a baseline for the sleep habits of the cadets.

During the fall semester, two additional datasets were obtained. The first was a set of self-reported activity logs, which are a daily portrayal of each cadet's life in fifteen-minute increments. The second, more objective data involved monitoring physical activity levels using a wrist activity monitor worn by the participants for one month. These activity watches recorded activity in one-minute intervals. The data were downloaded to determine time of sleep and naps during the period of recording. A clear picture of a cadet's sleep patterns was synthesized from the logs and actigraphy data.

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## **II. LITERATURE REVIEW**

This review focuses on sleep deprivation as it affects human performance, and specifically how sleep deprivation applies to human adolescents. Performance, as defined in this study, refers to cognitive functions, both simple and complex. The biological clock regulates levels of alertness, affecting performance in a predictable circadian pattern. Additionally, there is evidence that memory consolidation and long-term memory formation is affected by sleep deprivation (Stickgold, James, & Hobson, 2000; Fenn, Nusbaum, & Margoliash, 2003; Gais, Plihal, Wagner, & Born, 2000; Karni, Tanne, Rubenstein, Askenasy, & Sagi, 1994).

This review begins by discussing the innate sleep drive, and the daily fluctuations in alertness levels, which are degraded by sleep deprivation. It reviews the fundamentals of sleep architecture, including the stages of sleep. It also addresses sleep in adolescent humans and sleep in college-age students. Basic information about the contribution of sleep to the learning process is also presented.

### **A. SLEEP ARCHITCTURE**

#### **1. Circadian Rhythm and Homeostatic Sleep Drive**

Sleep is a reversible circadian process characterized by a state of unresponsiveness to the surrounding environment. People spend about a third of their lives asleep. There is documentation that a person will die after about two weeks of total sleep deprivation (Coren, 1997). While controversy exists about the exact amount of sleep required for individual humans, sleep is clearly a mandatory biological phenomenon.

Adult human beings are diurnal; the last 100,000 years of evolution has conveniently crafted a sleep-wake cycle in near harmony with sunrise and sunset. The suprachiasmatic nuclei of the hypothalamus is the part of the brain that carefully regulates fluctuating hormones, which shape an endogenous sleep and wake drive (Van Dongen, Rogers, & Dinges, 2003; Van Dongen & Dinges, 2000). These daily continuous biological processes follow a sinusoidal pattern known as the circadian rhythm. The circadian clock governs a tremendous number of biological rhythms such as endocrine

secretions, body temperature, sensory processing, and cognitive performance. It is helpful to address sleep architecture as a blueprint for the sleep engine, a recuperative refueling process upon which optimal performance is dependent (Dement, 1999).

By necessity, most humans adhere to a 24-hour clock. However, experimental evidence shows that in the absence of light or temporal cues, individuals have an innate 24.5 to 25-hour cycle (Horne, 1988). Human beings are constantly synchronizing themselves with the earth day. This biological clock is somewhat malleable, and its regulation is subject to cues called zeitgebers. Light, food, exercise, and social cues all contribute to synchronization of the circadian rhythm (Horne, 1988).

Fatigue and alertness, seen as opposing forces, can be measured by a variety of objective and subjective means, and occur in fluctuating strengths at different times of the day. As shown in Figure 1, the biggest dip in subjective sleepiness is temporally linked with slowed reaction time (RT) and degraded performance at a digit symbol substitution task (DSST) (Van Dongen & Dinges, 2000). Internal body temperature corresponds to these same peaks and troughs of fatigue and performance. In a healthy human, body temperature does not remain constant at 37 degrees Celsius but is lowest in the early hours of the morning, gradually rising during the day until it peaks in early evening (Hockey, 1983; Wright, Hull, & Czeisler, 2002 ).

As seen in Figure 1, the peaks and troughs that occur cyclically in human performance are directly related to time of day. Humans are traditionally at their highest level of alertness around 9am and 6pm. A trough in performance known as the midafternoon dip happens after noon. There is a common myth that it is food ingestion that makes one sleepy at this early afternoon time period; however, this innate drop in alertness occurs independent of food intake. There are individual differences in amplitude and placement of this dip. Carrier and Monk (2000) review the findings of circadian rhythms in performance.



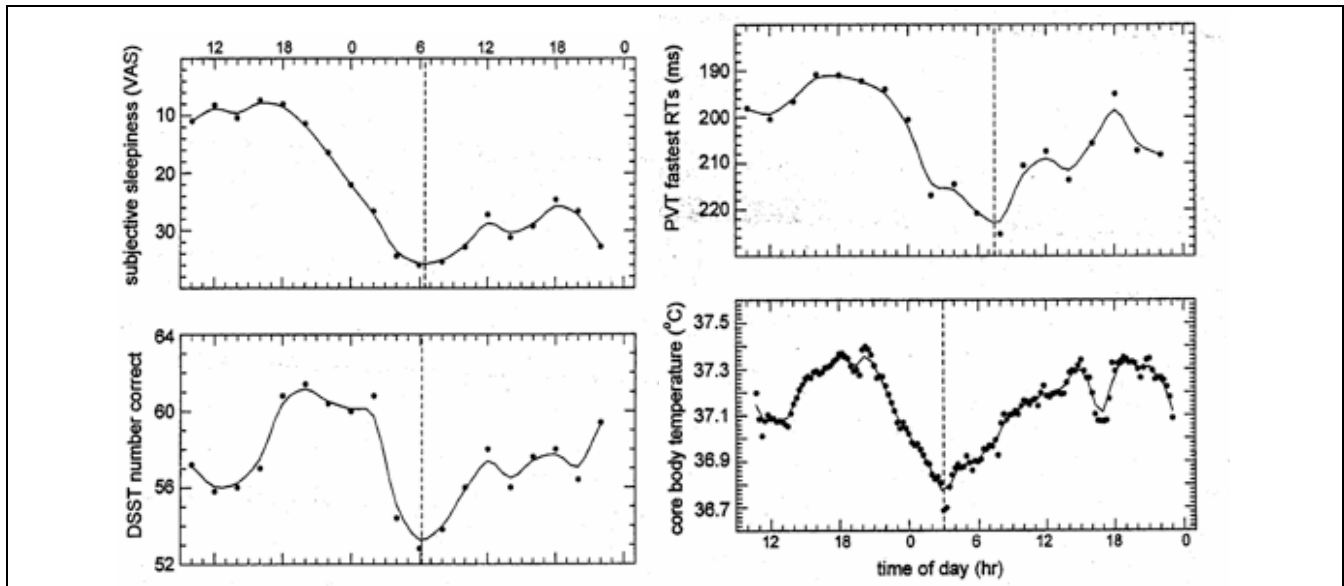


Figure 1. Temporal representation of circadian variation in a. subjective sleepiness; b. performance in a digit substitution task; c. reaction time task; d. body temperature. Van Dongen & Dinges, 2000.

In addition to the circadian mechanism regulating fatigue and alertness, there is a homeostatic need for sleep known as sleep propensity. Studies show that sleep propensity is dependent upon the amount of prior wakefulness (Carrier & Monk, 2000). If sleep is denied, an individual will feel more fatigued during the course of a day, but will also experience the same high and low arousal levels associated with the circadian rhythm. More sleep results in a subsequently lower homeostatic sleep drive.

The drive for sleep is a seesaw relationship between the circadian rhythm and homeostatic need for sleep, masked or enhanced by various external and internal factors. In summary, alertness wanes in proportion to the time spent awake. Sleep acts to restore alertness, but the effectiveness of the sleep in this capacity depends on the simultaneous circadian phase. If an individual tries to sleep during the circadian peak of alertness, the sleep will be less restorative. Additionally, a sleep-deprived person will benefit from this circadian peak of alertness when asked to perform in an extremely or totally sleep deprived state (Akerstedt, 1995).

## 2. Sleep Stages

Human sleep is divided into two separate stages, nonrapid eye movement (NREM) and rapid eye movement (REM), alternating throughout the course of a night of

sleep. Sleep onset begins in NREM, and continues through a series of four such stages, each of which is considered a “deeper” sleep, as it becomes increasingly difficult to awaken the sleeper. Each sleep stage is characterized by a slightly different level of neural activity or “brain waves,” as recorded by an electroencephalogram (EEG) and displayed in Figure 2. REM sleep generally follows Stage 4 sleep, and is named for its bursts of neural activity, which can be visually identified by the literal “rapid eye movements”, or twitching of the eyes. A large buildup in the homeostatic sleep drive due to sleep deprivation will hasten the transition to deep sleep (Carskadon & Dement, 2000).

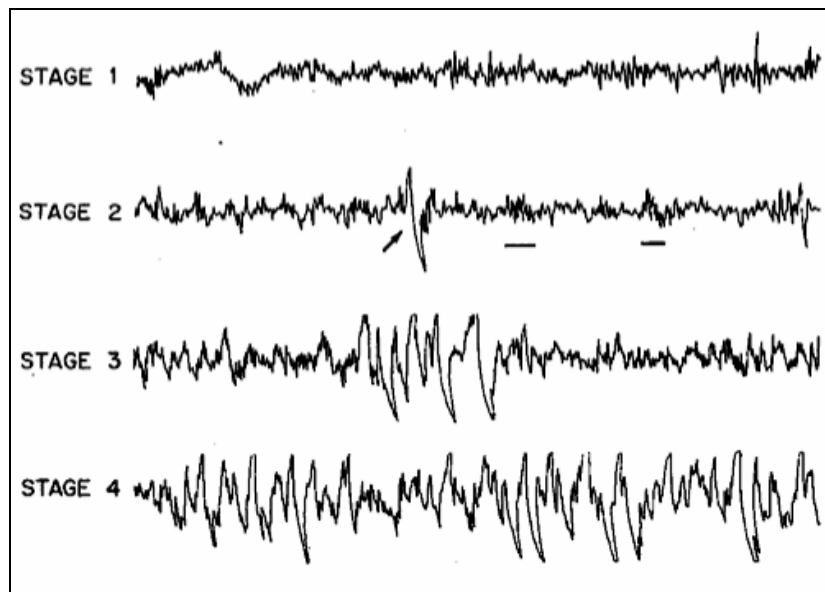


Figure 2. The stages of NREM sleep. Recorded with an electroencephalogram from a healthy 19-year old volunteer. Note the slow waves (delta) that characterize Stages 3 & 4. Carskadon & Dement, 2000.

When a person falls asleep for at least 10 minutes, upon awakening they will forget at least a few minutes before they entered Stage 1 NREM. This phenomenon is known as retrograde amnesia. It is thought that individuals with excessive sleepiness may have memory problems related to this phenomenon (Wyatt, Bootzin, Anthony, & Stevenson, 1992). Stage 1 sleep persists for a few (generally less than 10) minutes. A person can be easily awakened through verbal cues or physical contact during Stage 1 NREM sleep (Carskadon & Dement, 2000). Stage 1 sleep is often discussed as a transition to deeper stages, and is thought to be nonrecuperative in nature. Short periods

of sleep lasting 2 to 3 seconds due to boredom or fatigue are examples of Stage 1 NREM called “microsleeps” (Johnson, 1982; Horne, 1988).

Stage 2 sleep persists longer than Stage 1 – between 10 and 25 minutes (Carskadon & Dement, 2000). There is a slightly higher arousal threshold, and a slight difference on the EEG. During Stage 2, there is a gradual appearance of high-voltage slow wave activity (SWA) that is eventually classified as Stage 3. The transition to Stage 4 sleep occurs once this SWA occupies more than 50% of the recorded sleep activity. Together Stage 3 and Stage 4 sleep are known as slow-wave sleep (SWS) or sometimes “deep sleep”. After deep sleep, humans ascend rapidly into REM, a state often associated with dreaming and paralysis of voluntary muscles (Carskadon & Dement, 2000).

In Figure 7 on page 20, the distribution of sleep stages can be seen across a normal night of sleep, which when unrestricted, lasts about 8 hours. SWS dominates the earlier portion of the night, or first 4 hours, while REM dominates the second. For further information on changes in sleep architecture with age, see Carskadon and Dement, 2000.

## **B. SLEEP AND MEMORY CONSOLIDATION**

Human cognition is complex and may be elusive to measure. Improved human performance has been linked to a good night’s rest. Although there is controversy over the relationship between learning and sleep, current research cites sleep as a necessity for optimal memory formation and consolidation. There is debate over how sleep is involved with memory formation and whether this happens during REM, SWS, or a combination of the two (Gais, Plihal, Wagner, & Born, 2000; Karni et al., 1994). These studies will be reviewed in the following section.

In a study by Stickgold and colleagues at Harvard Medical School, two groups were trained in a visual discrimination task, a specific form of procedural learning. Following this training, the control group had three nights of unrestricted sleep, while the experimental group was denied sleep for the first 30 hours, and then allowed two days of recovery sleep. At test time, the experimental group denied feeling fatigued, as they had been allowed to “catch-up” on their sleep. Yet their scores on the task showed no improvement from the day of training. On the other hand, the control group had better

test scores, showing that sleep within the first 30 hours is absolutely crucial to task improvement (Stickgold, James, & Hobson, 2000).

Studies suggest that learned tasks are re-expressed and the corresponding neural pathways are reinforced and improved during sleep (Wilson & McNaughton, 1994). In rats given a spatial behavioral task, the hippocampal activity during subsequent SWS mimicked that of the cell activity from the earlier imposed environment, more so than previously recorded sleep episodes. This effect gradually declined in each post-behavior sleep session. The study concluded that “the neuronal states encoded within the hippocampus are ‘played back’ as part of a consolidation process by which hippocampal information is gradually transferred to the neocortex” (Wilson & McNaughton, 1994). Essentially SWS is an active process that seems to help hard-code synaptic pathways necessary to perform tasks.

When humans were given a visual discrimination task, Karni and colleagues (1994) found that learning was strongly dependent on the type of sleep received by the participants. Three groups had either normal, REM deprived, or slow-wave (SW) deprived sleep. Improvement at a recently learned task occurred after normal and SW deprived sleep. Improvement at a recently learned task occurred after normal and SW deprived sleep, but was lessened in the case of REM deprived sleep. However, for previously learned tasks, performance was more disrupted in the SW deprived condition than in the REM deprived condition. The study concluded that REM assists in memory consolidation as does the waking state, for the development of “procedural memory” or that which harnesses the skills of piano players or typists, and may have some relation to long-term association memory (Karni et al., 1994).

These studies emphasize the importance of sleep to learning, although differing about the role played by REM versus SWS in memory consolidation. More recent research supports a two-step model of memory consolidation that requires both REM and SWS. In a visual discrimination task, performance did not improve given REM if denied SWS, but a full 8 hour sleep of both REM and SWS saw a three-fold improvement to this group. Ultimately the study concluded that sleep is essential to the learning process (Gais et al., 2000)

Fenn and colleagues (2003) eloquently write “sleep facilitates the recovery and subsequent retention of material learned opportunistically at any time throughout the day. Performance recovery indicates that representations and mappings associated with generalization are refined and stabilized during sleep.” The tests were performed on an experimental and control group both in the morning and at night to account for the morning and evening preference types. Overall sleep was found to have stabilized learning (Fenn et al., 2003).

In testing the learning curve of a finger tapping sequence, Walker and colleagues (2003) reported that task performance improvement stopped after six hours of waking. The study concluded that the enhancement phase of this specific type of procedural learning requires sleep (Walker, Brakefield, Hobson, & Stickgold, 2003).

Given the controversial nature of these studies, it cannot be concluded that sleep is a requirement for learning. Yet evidence clearly has demonstrated the power of sleep to enhance certain specific kinds of cognitive learning. As a species, humans adapt to fit their environment, but optimization of learning may be achieved through a “perfect” amount of sleep.

### **C. ADOLESCENT SLEEP AND CIRCADIAN PHASE DELAY**

Adolescent sleep in humans can be separated into a distinct category, because the pubescent teenager has an innately different sleep drive than that of the adult or child. These sleep differences are apparent to parents of adolescents, though they may be unaware that the root of their child’s resistance to waking up early may not be due to laziness or spite. Increasingly, societal demands conflict with the transition stage from childhood to adulthood, interfering with a good night’s rest. Dr. Mary Carskadon, adolescent sleep expert at Brown University, summarizes sleep characteristics in adolescents: older teenagers sleep less than younger teenagers; bedtime is increasingly delayed in older teenagers; and teenagers tend to have a larger differential between weeknight and weekend sleep. The average adolescent, in the absence of enforced sleep onset or offset, parental intervention and weekday obligations, tends to go to bed later and wake up later (Carskadon et al., 1997). These changes are a consequence of both biological and environmental forces. Psychosocial forces such as a more active social

life, a higher academic load, and perhaps a higher involvement in extracurricular activities and/or employment can oppose the innate sleep drive. Biological forces during puberty delay the circadian sleep/wake drive later in the day (Carskadon, 2002; Carskadon et al., 1997).

### **1. Intrinsic**

Accompanying the fluctuation in hormones in teenagers is a marked decline in slow wave sleep, or a weaker homeostatic sleep/wake process (Carskadon, Acebo, & Seifer, 2001). The natural mechanism which regulates sleep and wake patterns is not so strong, and the nocturnal sleep time is not as efficient (less SWS and REM per total sleep period). Therefore, adolescents may appear chronically fatigued due to insufficient sleep and tend to have more “catch-up” sleep on the weekends.

Various ways to determine the differences in adolescent sleep drive have been explored; melatonin levels show a distinct biochemical difference between the pubescent teen and adult. Melatonin, known as the “hormone of darkness” is secreted by the pineal gland in the brain in the absence of light, and a natural trigger to fall asleep. Melatonin levels can be monitored by sampling a person’s saliva. During puberty, the level of nocturnal serum or salivary melatonin declines by up to 75%. The change in melatonin secretion during puberty is accompanied by inversely proportional changes in sleep-related luteinizing hormone (LH) secretion, paving the way for various sex hormones and sexual maturation in the young adult (Waldhauser & Steger, 1986). The offset of melatonin secretion is directly correlated with age, which further supports the theory of a phase delay in the circadian timing system triggered by puberty (Carskadon et al., 1997).

### **2. Behavioral**

A large sample of 6,632 public high school students in Italy was studied for two years (Giannotti & Cortesi, 2002). This study found that daytime sleepiness increased with age, as did falling asleep during class. The start time of schools ranged from 0745 to 0845. In general, students who attended those schools with an earlier start time had more irregular sleep schedules, complained more of daytime sleepiness, tended to fall asleep more in class, and reported a lower academic performance than those who attended schools with later start times. About 19% of students reported a difference in bedtime of three hours between weekday and weekend nights. “Catch-up” sleep on the

weekends has long been a sign of insufficient sleep during the week (Giannotti & Cortesi, 2002).

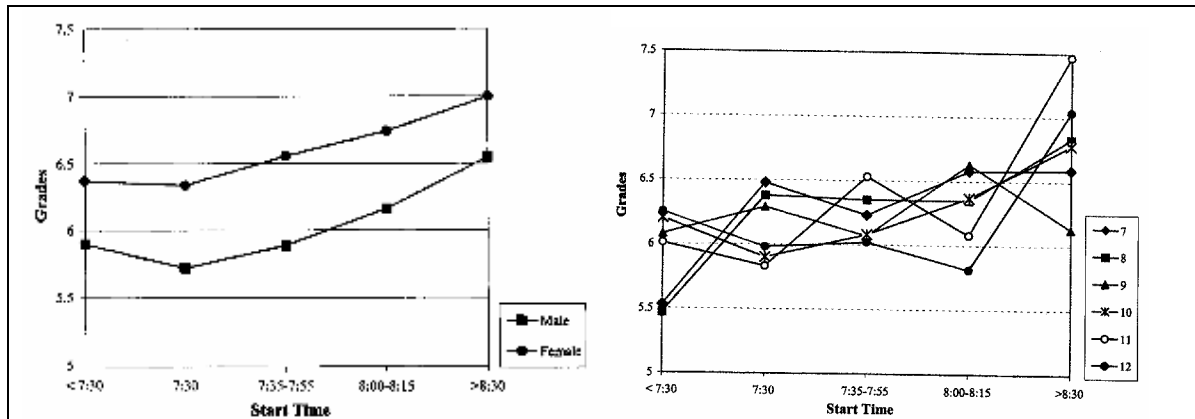


Figure 3. Two graphs which illustrate the improvement of grades with a later school start time, spread across year levels and gender. Wahlstrom, 2002.

Start time for school schedules tends to be driven by what is convenient for parents and athletic directors rather than addressing the inherent differences in adolescent sleep requirements. For most school districts, the adjustment is not made to start school later, a time more in harmony with the adolescent circadian phase. In Edina, Minnesota, a school district in the Minneapolis-St. Paul area, high schools shifted to a later start time for the 1996-1997 school year. Results were measured in terms of academic performance. Figure 3 illustrates how overall grades improved with the later start time benefiting the older adolescents more than the younger. There were no significant differences in the improvement between females and males (Wahlstrom, 2002).

### 3. College and Sleep

College students are often nearing the end of their adolescence. Yet many of these students balance a schedule that is equally as busy as that of the fully grown adult. In a longitudinal study of college sleep at Brown University, incoming freshman were found to have a significant reduction of net sleep between high school and college, and specifically an immediate two-hour delay in nocturnal sleep onset (Carskadon, Wolfson, & Tzischinsky, 1995). Over the first two years, there was a gradual increase in reported net sleep time coupled with a decrease in self-reported sleepiness, which suggests behavioral or physiological adaptations to the significant change in lifestyle (Acebo et al.,

1991). In general, college students go to bed later and wake up later than high school students and are prone to taking more naps (Carskadon & Davis, 1989).

Sleep habits have also been linked with college-level academic performance. In a study designed to determine the significance of many variables on first year college GPA, grades were negatively correlated with later weekday and weekend bedtimes, catch-up weekend sleep, and number of hours worked per week. Of all the variables considered, sleep habits and in particular wake-up times best accounted for the variance in GPA (Trockel, Barnes, & Egget, 2000).

#### **D. SLEEP AND IMMUNE FUNCTION**

Sleep deprivation has physiological consequences that affect thermoregulation, metabolism, hormonal changes, and locomotor activity and immune function. There is evidence on the microbiological level that natural killer cell activity is compromised under chronic sleep deprivation conditions. Sleep regulatory mechanisms share regulatory molecules with the immune system; consequently, host defenses are impaired by long-term sleep loss (Krueger & Fang, 2000).

#### **E. SLEEP DEPRIVATION**

##### **1. Dangers**

Human beings are constantly challenged to keep pace with the newest technology, especially in combat environments. Human error can have catastrophic results in the hands of overly tired military and civilian personnel. Sleep deprivation has been linked to numerous fatal catastrophes of the twentieth century, including the disaster at Three Mile Island Nuclear Power Plant in 1979, Chernobyl in 1986, and even the Space Shuttle Challenger Accident in 1986 (Mitler, Carskadon, Czeisler, Dement, Dinges, & Graeber, 1988). In 1988 alone the total economic cost of sleepiness-related accidents, both work and home-based, was estimated at \$43 to \$56 billion (Leger, 1994).

Sleep deprivation does not discriminate. It affects everyone. The problems caused by sleep deprivation pervade all types of industry, government, and even the military. Rosekind and colleagues (1994) performed numerous studies for NASA to combat the



dangers of fatigue in astronauts. In a study looking at fatigue in transpacific flights, the period of 90 minutes before landing was scrutinized for lapses of 5 seconds or greater, called “microevents”. For those 9 pilots who were not allowed an in-flight 40-minute nap, there were a total of 120 microevents. In the final 10 minutes of flight, they found 5 microsleep episodes among nine pilots (Rosekind et al., 1994).

Sleep loss will both increase the homeostatic sleep need, and alter circadian rhythm. It may also dampen morale, as well as self-reported energy levels, resulting in loss of competitive edge and negative feelings. Sleepiness will not only reduce quality of life, but is an early warning to later deterioration in human performance. Even though lack of sleep will not induce psychosis in a mentally healthy individual, brief episodes of hallucinations will occur under extreme sleep deprivation (Horne, 1993). However brief, these lapses run the risk of occurring during a dangerous military or industrial activity. In Figure 4, the temporal distribution of fatigue-related vehicular accidents is displayed. More accidents happen when the circadian alertness is around at its nadir – in the early morning hours and after lunch.

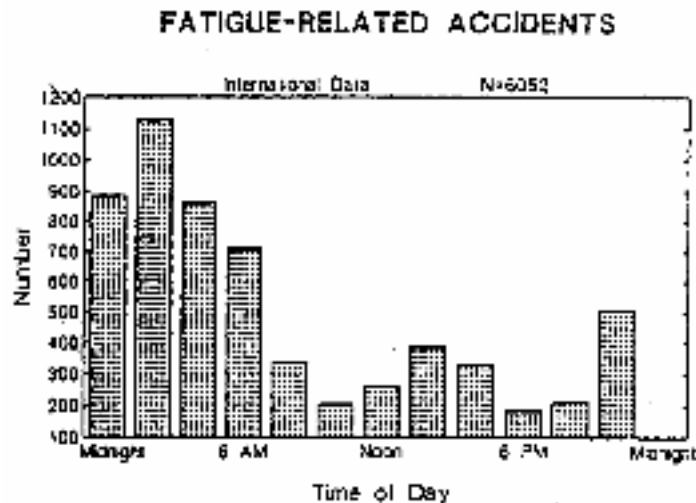


Figure 4. Temporal distribution of fatigue-related car accidents as a function of daytime. Mitler et al., 1988.

## 2. Performance Degradation

Several studies have attempted to model performance degradation in the laboratory using experimentally induced sleep deprivation. Belenky and colleagues (2003) used the psychomotor vigilance test (PVT), measured sleep latency, and

subjective sleepiness to quantify alertness and performance in a dose-response experiment. At baseline, all groups received a mandatory 8 hours of sleep for 3 nights. Subjects were randomly assigned to treatment groups of 3, 5, 7, and 9 hours of sleep per night for a 7 day period. In Figure 5, the results show the mean PVT speed and standard error over the entire experiment. In the seven days of sleep restriction, performance in the 5 and 7 hour groups decreased and then stabilized, but performance in the 3 hour group continued to degrade, showing no signs of stabilizing. Performance stayed the same in the 9 hour group. In the 3 days of recovery sleep, performance of all three sleep-deprived groups improved, but did not reach the baseline levels.

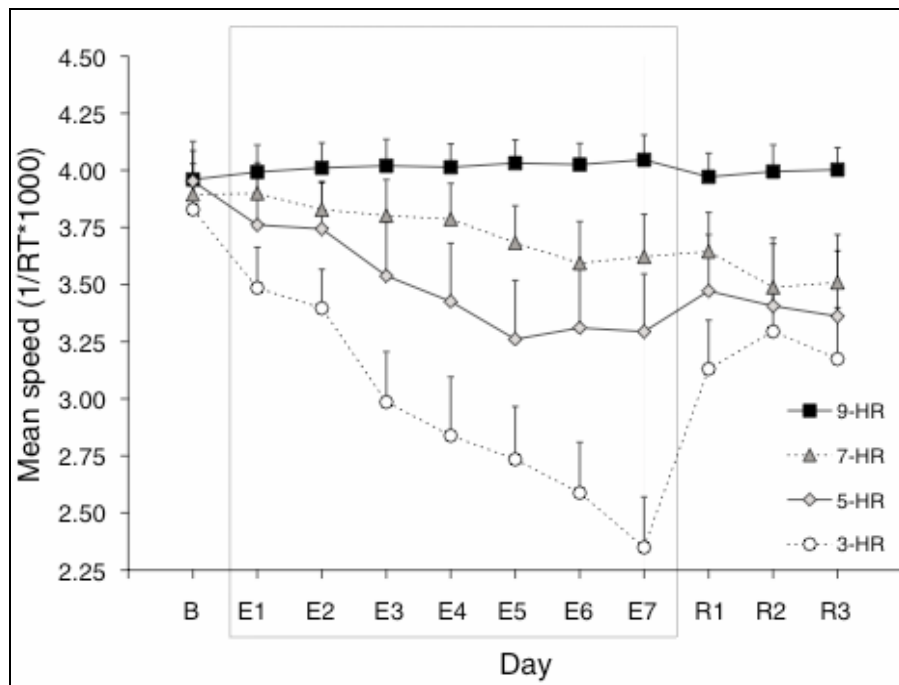


Figure 5. Dose-response curve for performance in a reaction-time task in groups with 3, 5, 7, and 9 hours sleep. Belenky et al., 2003.

In a similar study conducted by Van Dongen and colleagues (2003), sleep restriction was induced in one of three sleep doses: 4, 6, or 8 hours per night. This restriction was maintained for 14 consecutive days. The participants were a group of 48 healthy adults, and the experiment was carried out under carefully monitored laboratory conditions. Chronic sleep deprivation of between four and six hours per night for two weeks resulted in cognitive performance deficits equivalent to performance of those individuals who were totally sleep deprived for 2 to 3 days. Figure 6 shows a graph of

performance changes by sleep group including subjective sleepiness scores, digit substitution task, and serial addition/subtraction task over 14 days.

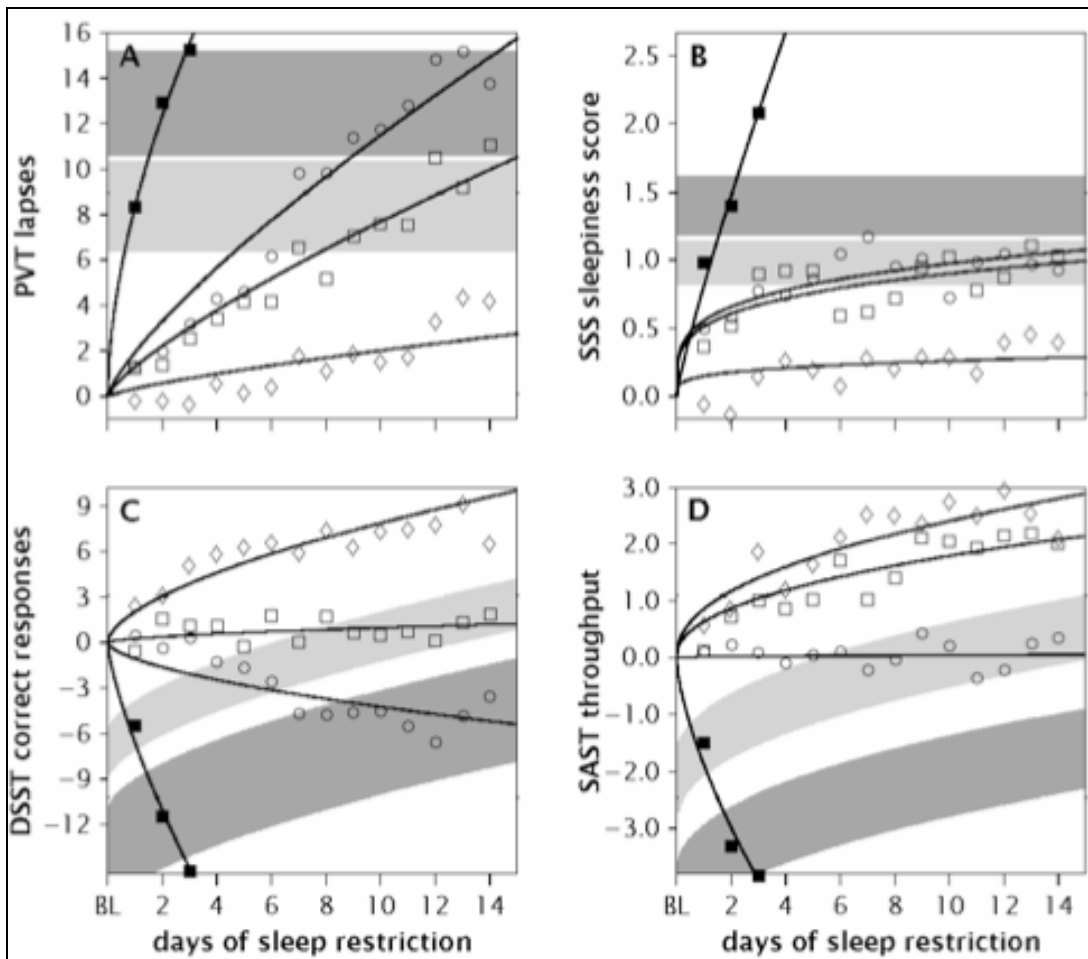


Figure 6. Results from dose-response study of 8( $\diamond$ ), 6( $\square$ ), 4( $\circ$ ) hour chronic sleep conditions over 14 days. SSS sleepiness score = subjective sleepiness; DSST = digit substitution task; SAST = serial addition/subtraction task. These performance results are compared with total sleep deprivation( $\blacksquare$ ) for 3 days. Van Dongen et al., 2003.

Both these studies suggest that under chronic sleep deprivation conditions, human performance degrades and then stabilizes at a certain level<sup>2</sup>. Another important conclusion from the experiment is that the effects of chronic sleep restriction were not limited to certain parts of the day. In addition, inclusion of a control group offers further evidence that the degradation of performance is not likely to be attributed solely to

<sup>2</sup> The case of 3 hours per sleep per night in Belenky, 2003 is inconclusive; performance in the 3 hour sleep group does not appear to stabilize by the end of experiment.

boredom, monotony or non-compliance, as degradations would have appeared in the control group as well.

A study reported by Van Dongen and colleagues (2003) showed a modest positive relationship between average sleep duration 5 days prior to experiment and rate of increase in PVT lapses over 14 days. This correlation suggests that those who had sleep deprived lives as a norm may have been less affected by the 14 days of imposed sleep restriction. This finding suggests that perhaps there is an adaptive response to chronic partial sleep deprivation. A competing theory is that these are the individuals who, by their nature, need less sleep. In terms of subjective sleepiness, findings show that under conditions of chronic sleep restriction, subjects cannot accurately assess their own sleepiness levels (Van Dongen et al., 2003).

The physiological consequences of sleep deprivation are more difficult to quantify. Even though physical work capacity may be unchanged by a high sleep debt, physical speed decreases as the desire to rest grows stronger. For more information on sleep loss and physical work capacity, see Naitoh, Kelly, and Englund (1989). During long bouts of sleep deprivation, humans may also develop an apparent tolerance to insulin. As glucose levels in the blood increase, these changes mimic the symptoms of diabetes (Naitoh, Kelly, and Englund, 1989).

Sleep deprivation negatively affects functions of the prefrontal cortex (PFC) (Horne, 1993). The prefrontal cortex is the part of the brain that is credited with maintaining wakefulness and arousal, as well as other important cognitive functions including planning and discrimination. Lesions in the prefrontal cortex can lead to apathy, indifference, and reduced motor activity. In terms of neural activity, the prefrontal cortex is most quiescent during periods of slow wave sleep. With total sleep deprivation (TSD), certain PFC functions are degraded; these degradations are reversed following recovery sleep.

There is a common myth that given a certain motivation or interest in an activity, the negative effects of extreme sleep deprivation can be overcome by will power. Yet for highly complex cognitive tasks, sleep deprivation leads to increased visual and auditory distraction, which can hinder learning. For tasks less than 10 minutes, sufficient interest

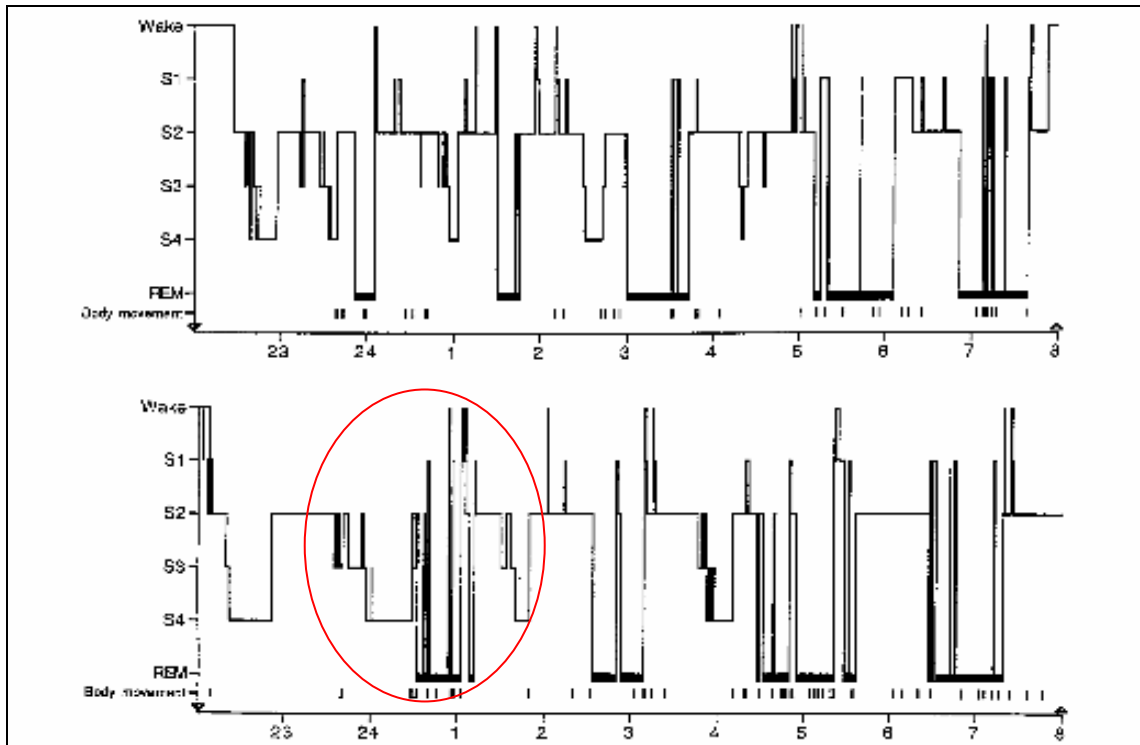
or arousal can overcome cognitive slowing of sleep deprivation. This effect is known as “masking” (Monk, 1990). Yet for tasks that involve the prefrontal cortex (PFC), performance decrements are visible much earlier (Harrison & Horne, 2000).

It is harder to mask performance decrements with motivation or incentive with PFC-related tasks as compared to non-PFC-dominant tasks such as vigilance tests. As sleep expert Jim Horne wrote,

So many of the manifestations of TSD are similar to those of PFC deficit: not only impaired divergent thinking, increased distraction by irrelevant stimuli, flatness of speech, but apathy and childish humour (Horne, 1993).

### **3. Sleep Architecture**

Following exposure to sleep deprivation, normal sleep architecture is altered. The duration and pattern of sleep deprivation (i.e., sustained wakefulness or chronic partial sleep deprivation) determines the sleep architecture during recovery sleep. The percentage of Stage 3 and 4 sleep over the course of a night is maintained or increased when sleep time is chronically curtailed (Borbely, Baumann, Brandeis, Strauch, & Lehmann, 1981). See Figure 7. Accompanying the increase in SWS is a delayed onset of REM. Carskadon and colleagues report that REM latency for a sleep-deprived group of adolescents was 155 minutes, while the control group averaged 103 minutes (Carskadon, Acebo, & Seifer, 2001).



**Figure 7. Sleep Architecture.** The first graph shows a normal night of sleep. The second is from a night of recovery sleep. Notice the delay in the first REM cycle and the density of SWS in the recovery night. Carskadon and Dement, 2000.

## F. COUNTERMEASURES OF FATIGUE

There are many techniques that are used to counteract fatigue and enhance alertness, such as stimulants, rest breaks, and naps. Despite numerous short-term studies, few experiments have been designed to address the long-term effects of these fatigue countermeasures. Dinges (2004) suggests that while naps and caffeine may be effective countermeasures when used intermittently, perhaps the chronic use of caffeine or naps alters the recuperative effects of either method. The effects of habituation to fatigue countermeasures have not yet been fully assessed. The following section discusses several possible means of increasing alertness.

### 1. Melatonin

In humans, melatonin is a naturally excreted hormone from the pineal gland. It is released in a circadian pattern, with low levels present during the day and higher levels at night, peaking around 2 a.m. Melatonin is naturally excreted at an elevated level for a duration of 8 to 9.8 hours each night, the onset of which varies considerably between individuals (Waldhauser & Steger, 1996).

Melatonin provides an intrinsic cue to fall asleep and its secretion can be interrupted by exposure to light on the retina (Horne, 1998). It is frequently used to treat insomnia, or to reset the circadian clock in the case of jet lag. An antioxidant, melatonin has been called the “anti-aging” pill. Available without a prescription but not yet approved as a sleep aid by the FDA, there is no evidence of harmful side effects of melatonin. However its use may be related to a delayed onset of puberty in adolescents (Kitay, 1954).

## 2. Caffeine

Caffeine is commonly used to combat daytime fatigue. It acts as a stimulant to the brain and body, and has a half-life that varies between three to seven hours in the human body (Gillin & Drummond, 2000). Table 1 shows common sources of caffeine and their caffeine content. Despite the positive effects of caffeine on alertness in sleep deprived individuals, caffeine has also been known to have deleterious effects on sleep, decreasing net total sleep by increasing the number of wakings (Stepanski, 2000).

Source	mg of Caffeine
brewed coffee	100-150
instant coffee	85-100
tea	60-75
12 oz. Cola	40-75
cup of cocoa	50
OTC cold medications	15-60
OTC stimulants	100-200

Table 1. Examples of caffeine sources and their caffeine content (Gillin & Drummond, 2000).

Caffeine has been found to enhance performance in U.S. Navy Sea-Air-Land (SEAL) training (Lieberman, Tharion, Shukitt-Hale, Speckman, & Tulley, 2002). In a dose-response study, sixty-eight SEAL trainees were randomly assigned to receive either 100, 200, or 300 mg of caffeine or placebo after a 72 hour period of sleep deprivation. Following treatment, the trainees took tests, which included measurements of caffeine blood levels, vigilance on a visual task, mood, self-reported sleepiness, marksmanship, and different types of learning and memory. Caffeine intake was found to have improved performance and mood in a dose-related manner. The trainees who received 200 and 300 mg dose of caffeine significantly improved in their visual vigilance, reaction time, self

reported fatigue and sleepiness, and alertness. Performance on the marksmanship task was not enhanced by the use of caffeine. The fatigue-fighting effects observed with caffeine were most effective when administered 1 hour before the tests (Lieberman et al., 2002).

### **3. Napping**

Napping can be used as a tool to enhance human performance. However, the length and placement of a nap during the day is critically important when considering its restorative value. Debate continues about how beneficial naps may be, but the majority of the evidence reports that while a nap may hinder performance through sleep inertia in the short term, this handicap is outweighed by the long-term benefits of napping.

Sleep inertia refers to the period after an individual awakens when they feel confused, sluggish, disoriented, and/or not motivated. There is a significant performance impairment in cognitive tasks during sleep inertia (Dinges & Kribbs, 1991). Sleep inertia following a nap can pose a short-term problem for performance. In a report written by the Naval Health Research Center, sleep inertia was found to worsen in proportion to the cumulative sleep debt (Naitoh, Kelly, & Babkoff, 1991). Additionally, the placement of the naps did not influence either the amount of sleep inertia or the long-term benefits of the nap. The level of sleep inertia depends more upon the stage of sleep during which the nap is terminated than the actual timing of the nap. More severe sleep inertia is associated with awakening from SWS (Naitoh et al., 1991).

These findings about sleep inertia were confirmed in a study done by Lumley, Roehrs, Zorick, Lamphere, and Roth (1986). Four different groups were given 15, 30, 60, and 120 minute naps. Differences in human performance following these naps did not appear within two hours of any nap. This 2 hour window corresponds with the period of sleep inertia after a nap (Naitoh, 1981). However, after the sleep inertia dissipated, alerting effects of the naps were measurable. SWS peaked in the 60 minute nap, while the 120 minute nap contained more REM and Stage 2 sleep (Lumley et al., 1986). Further research needs to be done on the benefits of sleep stage on recuperative value.

Napping had alerting effects in sleep-deprived individuals, which were systematically related to the duration of the nap. After sleep inertia in the participants



dissipated, the alerting affects were measurable and increasing. The highest level of alertness for the 8 hrs of testing was achieved with a 60-min nap, although alertness never reached baseline levels. Increasing the nap duration to 120 minutes produced no further increase in alertness. Increased alertness was associated only weakly with increasing amounts of SWS (Lumley et al., 1986).

Dinges and colleagues (1987) also showed that naps increased alertness after two hours, especially in reaction time (RT) tasks. Most of the subjects were not aware of the improvements. The study also concluded that the placement of the nap was not important, but that any nap at all was important before a night of sleep loss (Dinges et al., 1987).

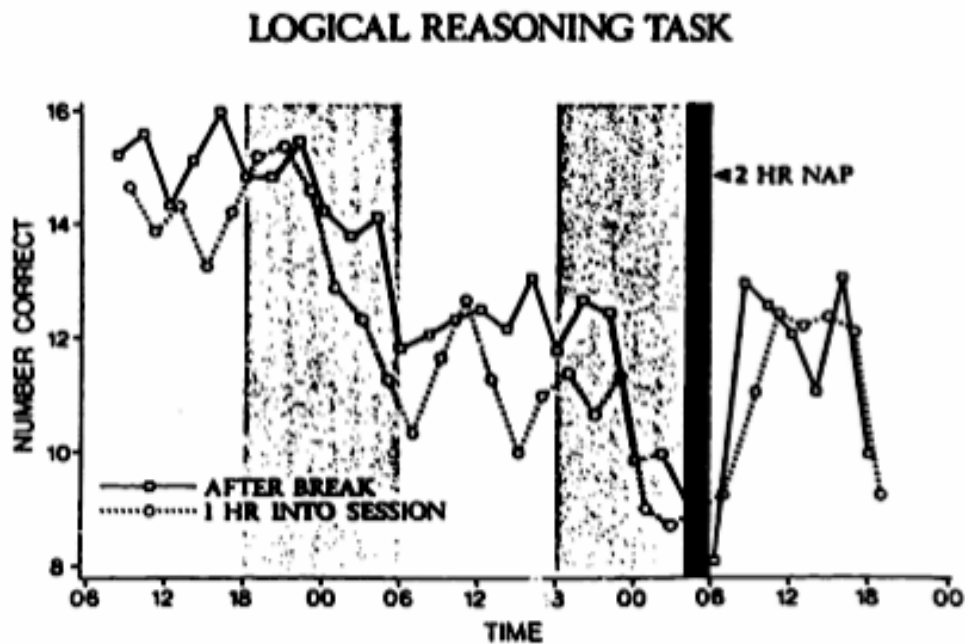


Figure 8. Performance throughout the daytime at a short (2 minute) logical reasoning task. Note the recuperative effects of a 2 hour nap at 0400. Naitoh & Angus, 1987.

Doctors and nurses in the emergency room at the hospital must work long hours, often fighting their circadian clock. A study in Japan reported that giving nurses a 2 hour nap during a 16 hour night shift significantly decreased their self-reported fatigue after a variable period of sleep inertia (Takahashi, Arito, & Fukuda, 1999). Another study in France showed almost the same thing with shiftworkers in an industrial plant -- a short nap during the night shift can be considered as a positive way to counteract the low level

of vigilance that occurs during the late part of the night (Bonnet, Muzet, Winter-Dill, Bailloeuil, Bitouze, & Bonneau, 2001).

## **G. MORNINGNESS-EVENINGNESS**

Scientists have observed a tendency for individuals to exhibit a diurnal preference in their sleep and work/wake habits. Decades of research has culminated in a general acceptance of the existence of morningness-eveningness typology, or chronotype (Horne, 1976). Individuals may either prefer to stay awake late at night and sleep late in the morning (“owls”) or go to bed and awaken early (“larks”). The individual who displays neither of these extremes is termed a “robin” or a “hummingbird” (Smolensky & Lamberg, 2001).

It is thought that morningness-eveningness is a fairly stable trait, although a positive correlation between age and morningness has been found (Taillard, 2004). In a study of Taiwanese early adolescents (grade 4 to 8), school grade level is linked with the transition to eveningness (Gau 2003). In another study comparing the sleep-wake patterns between adolescents and young adults (ages: Group 1 mean = 15.7 years, Group 2 mean = 24.5 years) morningness-eveningness ratings were associated with melatonin onset, and the two groups had similar physiological and sleep patterns (Lamberg, 2000).

## **H. QUANTIFYING SLEEP**

Methods to monitor sleep are often intrusive and taxing for both the scientist and the participant, requiring many late nights in a laboratory. Polysomnography (PSG) is the standard used to quantify sleep in a laboratory. The beauty of actigraphy is its relatively non-invasive protocol, and the ability for a wrist-watch like device known as a wrist-activity monitor (WAM) to collect sleep data over a long period of time. These WAMs are known as actigraphs, miniature accelerometers that monitor and record movements in as little as one minute intervals (Acebo et al., 1999).

Actigraphs have been known to differ in their sensitivity. Additionally, there are different algorithms called “scoring programs” to interpret the data. In the 1995 ASDA review, agreement between actigraphs and laboratory-based sleep recordings is greater than 0.85 (Sadeh, Hauri, Kripke, & Lavie, 1995). However, these findings were based on

nighttime recordings, and not during daytime. Discrepancies are more frequent in the case of insomniacs and those with restless sleep. A problem also occurs when daytime activities such as watching television mimic sleep. Despite the possible negative aspects about the accuracy of actigraphy, aggregation of data is a better predictor of average sleep. The general consensus recommends more than five days of recording for accuracy (Sadeh, Avi, & Acebo, 2002; Acebo et al., 1999).

## **I. MODELS OF FATIGUE AND PERFORMANCE**

Scientific models of fatigue and performance are the product of efforts to predict human performance as it relates to sleep regulation and circadian dynamics.

The United States Department of Defense (DOD), in the interest of effective war fighting during CONOPS and SUSOPS, has sponsored the development of homeostatic fatigue model to help advise and develop management strategies for fatigue. Dr. Steve Hursh, formerly an Army Colonel at WRAIR and now at Science Applications International Corporation (SAIC), has developed a Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) Model for the Air Force Research Laboratory. At the heart of SAFTE is the concept of a sleep “reservoir”, which is maintained and rejuvenated during sleep, and depleted during waking hours. It is the homeostatic component of the sleep model. The rate of reservoir recovery during sleep is proportional to total sleep deficit, and there is a clear rebound in performance during recovery sleep after chronic sleep restriction. The SAFTE model superimposes this reservoir concept with sleep inertia and the circadian mechanism to predict performance. Currently SAFTE does not take into consideration environmental or internal stressors such as motivation that might enhance alertness, or a battlefield, which might degrade performance. One limitation of the SAFTE model is its inability to account for age, morningness-eveningness types, or sleep requirement for maximum performance as it differs between individuals. While limited in terms of accounting for a given individual’s performance, the model works very well for larger groups (Eddy & Hursh, 2001).

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### **III. METHOD**

The objective of this thesis is to identify a well-defined structure for the pre-CBT sleeping patterns of the West Point Class of 2007 and their sleep during their first academic semester. It is part of a four-year longitudinal study following the class from their report date in June of 2003 through commissioning in May of 2007. Basic survey and demographic data about all the cadets was obtained at the foundation of the study. During the fall of the first academic year, a sample of the plebe class stratified by gender, unit, and athletic status wore Wrist Activity Monitors (WAMS) and kept activity logs for a period of 30 days to record the amount of sleep they were getting over this time period.

Using known information about performance degradation under severe sleep deprivation, one can derive the relative cognitive capacity of the cadets over the course of this time period. This research entails obtaining and interpreting survey data and activity logbooks, analyzing “sleep watch” data, understanding the plebe West Point Schedule and academic timeline, as well as establishing a measure of performance for the cadet.

#### **A. PARTICIPANTS**

The participants for this four-year study are 1289 cadets at the United States Military Academy in West Point, NY, all from the Class of 2007. Ranging in age from 17 to 23 years upon entrance, the mean age of the participants was 18.7 years, with a standard deviation of about 11 months. All subjects underwent intense medical screening prior to their acceptance and are therefore assumed to be fully healthy. In addition, candidates who are admitted to USMA are required to meet minimum standards on the SAT or ACT, have demonstrated a potential for leadership and aptitude, and are members of an ethnic and gender-diverse population of scholars and athletes. Because of the rigors of the admission’s process, the Class of 2007 is not a random sample of the entire college-age population, but clearly a snapshot of a certain cross-section of this population. An average class at West Point has a profile similar to that of the Class of 2005 as seen in Figure 9.

A stratified sample of seventy-nine students ranging from age 17 to 22 participated in the fall portion of the study. The mean age of these participants was 19.25

years with a standard deviation of approximately one year. The sub-sample was selected to represent all gender, unit, and athletic status (participation in a competitive sport).

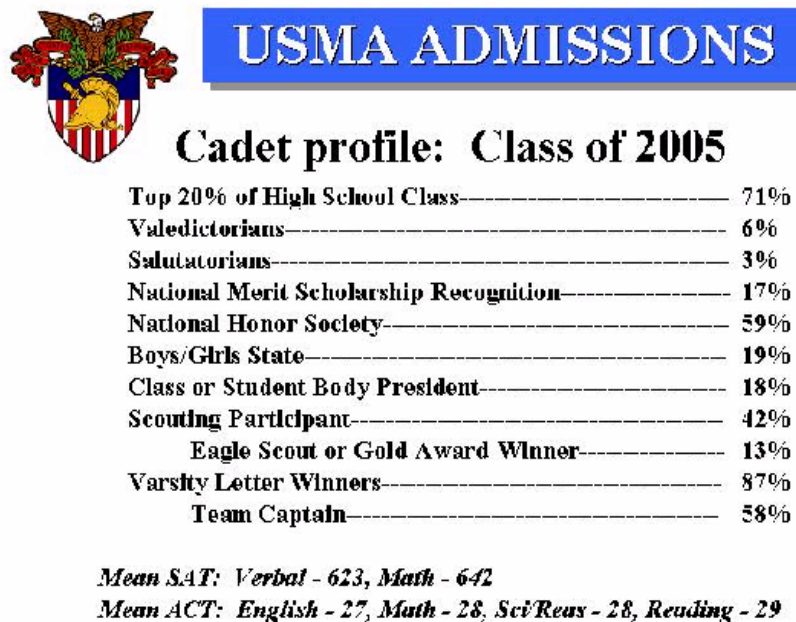


Figure 9. Typical cross section for an admitted class of students, as seen on the Admissions homepage for the United States Military Academy at West Point, NY.

Important to this study is a thorough understanding of the typical daily schedule of a Fourth Class cadet, which is rigid and predictable. The entire Corps of Cadets (approximately 4,000 students) is expected to adhere to a schedule similar to the one in Table 2 from Monday through Friday. In addition to these generic commitments, the first-year cadets, known as plebes, are also part of a tradition of indoctrination into the Army, overseen by their upper class who task them with a heavy load of extra duties, in addition to their academic responsibilities. The atmosphere is similar in philosophy and regime to “basic training.” For instance, reveille is at 6:30 a.m., but a large number of plebes wake up as early as 5:00 a.m. to do things such as deliver laundry, shine shoes, learn professional military knowledge, etc. These cadets often take opportunistic naps. During the week, the Fourth-Class cadets are not allowed to leave the campus ground. Their weekends are their only flexible days, when they may get extra sleep, and have time for social activities. They are granted “walking privileges” (permission to leave

campus) on Saturday from the time of their last military obligation to 1:00 a.m. on Sunday, and on Sunday from 5:20 a.m.-7:00 p.m.

<i>Morning:</i>	6:55-7:30	Breakfast
	7:35-11:45	Class or study
<i>Afternoon:</i>	12:05-12:40	Lunch
	12:45-1:40	Commandant/Dean Time
	1:50-3:50	Class or study
	4:10-5:45	Intramural, club or intercollegiate athletics; parades; extracurricular activities; or free time
<i>Evening:</i>	6:30-7:15	Supper (optional except Thursday)
	7:15-7:30	Cadet Duties
	7:30-8:30	Study Conditions/Extracurricular activities
	8:30-11:30	Study time
	11:30	Taps
	12:00	Lights Out

Table 2. Typical day of a West Point cadet.

## B. PROCEDURES

Members of the Class of 2007 reported for duty at the United States Military Academy at the end of June, 2003 to participate in six weeks of CBT. Within 72 hours, all 1289 members of the Class took a Pre-CBT survey that asked them for basic demographic data and information about their sleep patterns during the month prior to their arrival at the Academy. They were also asked to provide information about their use of tobacco products, their intake of caffeine, and any over-the-counter or prescribed medications they had taken recently. The Pre-CBT survey also included questions from the PSQI, in order to assess the quality of sleep each individual received prior to their reporting to USMA.

In the Fall Academic semester, seventy-nine cadets were asked to wear WAMs manufactured by the Mini Mitter Company and simultaneously fill out activity logs to complement this electronic data collection. They were issued the watches 16 November, and returned the watches and sleep logs as late as 19 December. The data from the watches were then downloaded, and analyzed using commercially available sleep analysis software.

## **C. APPARATUS**

### **1. USMA Pre-CBT Survey**

The pre-CBT survey was administered to collect basic demographic information about the participants, their normal sleep habits, and basic lifestyles. See Appendix A for details of the questions. The results from this survey were then entered by hand into a large spreadsheet data file. From this spreadsheet, the data were cleaned in order to account for typographical errors. Analysis was primarily descriptive in nature but included some parametric and non-parametric statistical tests.

### **2. Pittsburgh Sleep Quality Index (PSQI)**

Some questions on the pre-CBT survey were taken from the PSQI, a self-rated questionnaire designed to measure sleep quality in clinical populations by looking at a 1-month long interval. Nineteen individual items generate seven scores, which include: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction. A review of the reliability of this survey in the *Journal of Psychiatry Research* in 1989 asserted that the PSQI is useful to both psychiatric clinical practice and research activities (Buysse et al. 1989).

### **3. Activity Logbooks**

Subjects were issued activity logbooks, for which they could transcribe their daily activities in fifteen-minute increments. An example page from the logbook can be seen in Figure 10. Sleep was divided into two different activities: “sleep” and “naps.” Other activities ranged from playing video games and watching television to studying or eating, all tailored to the environment at the Academy. Subsequently the data were collected and entered in an excel spreadsheet. The activity log compliance of the cadets varied greatly. Approximately 40 activity logs were used and even those may have contained only a week of data.



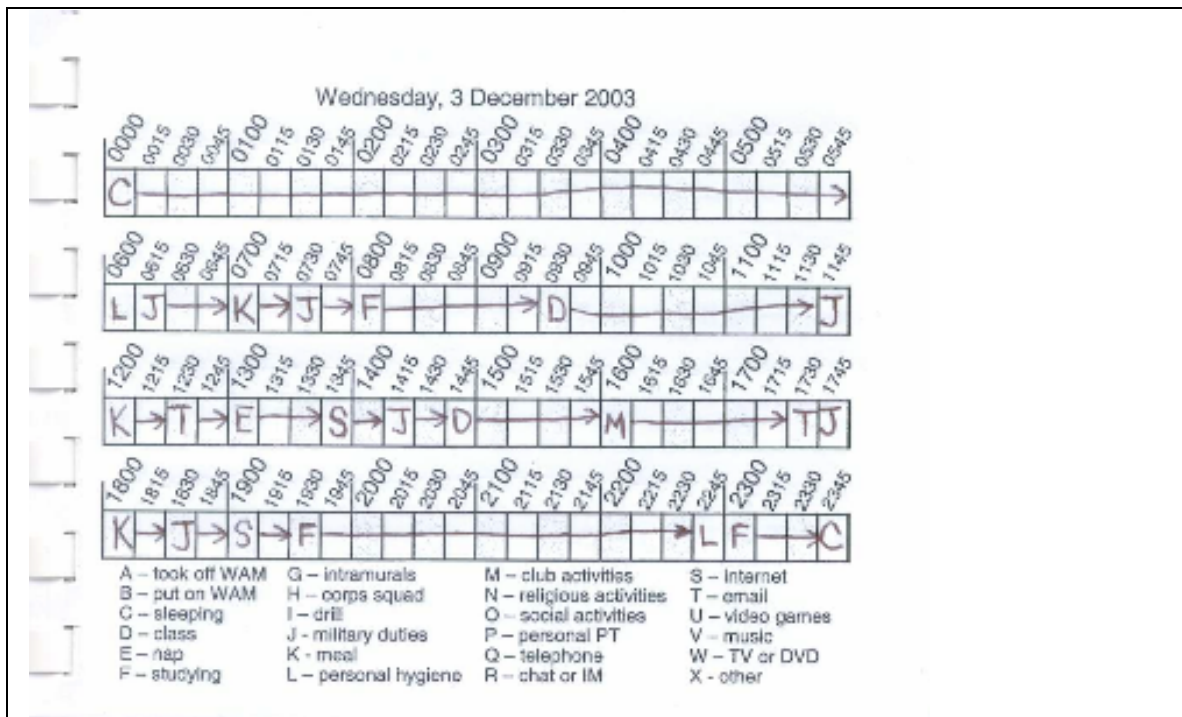


Figure 10. Example of page from Activity Log. Note the difference between “C” which is contiguous nighttime sleep, and “E” which is indicative of a nap.

#### 4. Actigraphy

Subjects were issued Actiwatches, a registered trademark of Mini Mitter Company in Bend, Oregon. These WAMs, called “sleep watches” by the participants, have an accelerometer that records long term gross motor activity in human subjects. Sleep watches are an effective and noninvasive technique to monitor epochs of the sleep and waking cycles in human subjects over a long period of time. Prior to data collection, the devices were calibrated to align with the current time and date, and initialized to group the data into 1-minute intervals of time known as the epoch length. At the conclusion of the study, the watches were collected and the data from the Actigraphs were downloaded and analyzed using Mini Mitter’s Actiware software program. The software facilitated the calculation of sleep duration, sleep efficiency, and sleep latency.

Actiware is a Windows based sleep analysis tool, which can take the Actiwatch data and generate visual and quantitative representations of activity level. Activity can be represented visually in an Actigram window. Information such as sleep start and end times, time in bed, assumed sleep time, and sleep efficiency can be exported using the Actiware-Sleep software program that allows for cutting and pasting the data.

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## IV. RESULTS

### A. PRE-CBT SURVEY

The pre-CBT survey provided a snapshot of the Class of 2007 for June of 2003. Those portions of the survey that were left blank or had missing values were omitted from the descriptive summary. The questions regarding lifestyle and sleep habits pertained to the 30 days prior to CBT report date. The following commentary discusses the measures of central tendency of the data, and correlations that were found between variables.

#### 1. Age

The average age of the cadets was 18.7 years, and ranged from 17 to 23 years of age (n=1281). There were 8 missing values. Figure 11 shows the distribution of age. Incoming cadets were required to be high school graduates less than 23 years of age at the time of admission to USMA.

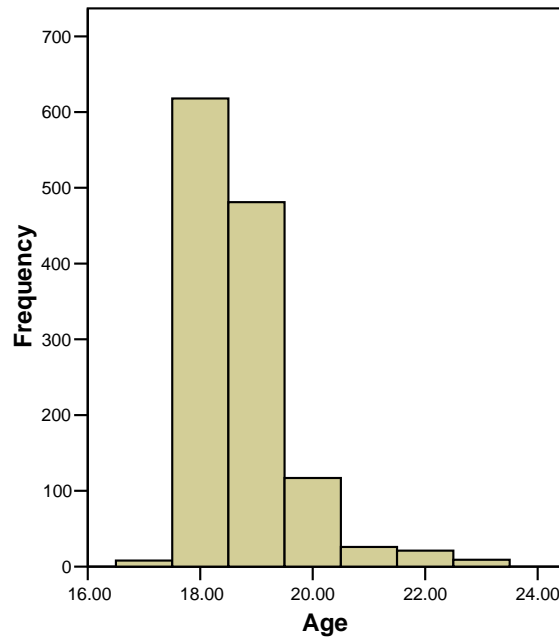


Figure 11. Frequency distribution for the reported age of cadets, n=1281.

From pre-CBT survey, 2003.

## 2. Average Nightly Sleep

On the pre-CBT survey, cadets reported both their average bedtime and wake-up time for the 30 days prior to CBT. Overall average time asleep per night was derived from the difference between these two variables and named “Delta Sleep,” to more easily distinguish this measure of sleep from the two other measures of sleep used in this analysis. The mean for Delta Sleep (n=1248) was 8.5 hours, with a standard deviation of 1.7 hours. Delta Sleep ranged from 2 to 14 hours; sleeping more than 14 hours was deemed erroneous and excluded.

Cadets were also asked to estimate how many hours of sleep they were getting each night. This was the second measure of overall average sleep and is referred to as “Reported Sleep.” Cadets tended to respond to this question on the whole or half hour. Individuals who failed to respond, one person who claimed to never sleep, and 23 cadets who reported getting over 24 hours of sleep per day were all excluded from further analysis. The mean Reported Sleep (n=1218) was 7.76 hours with a standard deviation of 1.46 hours. Reported Sleep ranged from 3 to 12 hours.

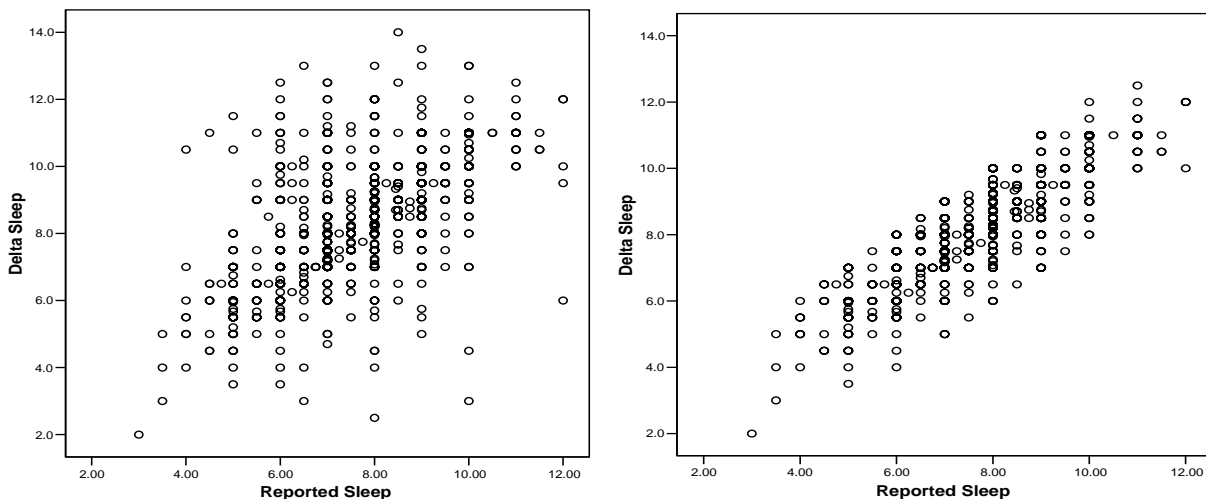


Figure 12. Scatterplots of Reported Sleep against derived total sleep, Delta Sleep from pre-CBT survey, 2003. The first is from the original sample (n=1203), and the second is a subset called Cleaned cadets (n=1056).

The two measures of nightly sleep, Delta Sleep and Reported Sleep, were very different for a large number of cadets. Therefore, a subset of the population was extracted to screen out those individuals with a large discrepancy between Delta Sleep and Reported Sleep (e.g., one cadet had a Delta Sleep of 18 hours and a Reported Sleep

of 9.5 hours). “Cleaned cadets” is a subset of 1056 cadets whose difference in Reported Sleep and Delta Sleep was less than 2 hours. The two scatterplots in Figure 12 show how the data were trimmed. The cleaned distributions for Reported Sleep and Delta Sleep are in Figure 13 and Figure 14, respectively.

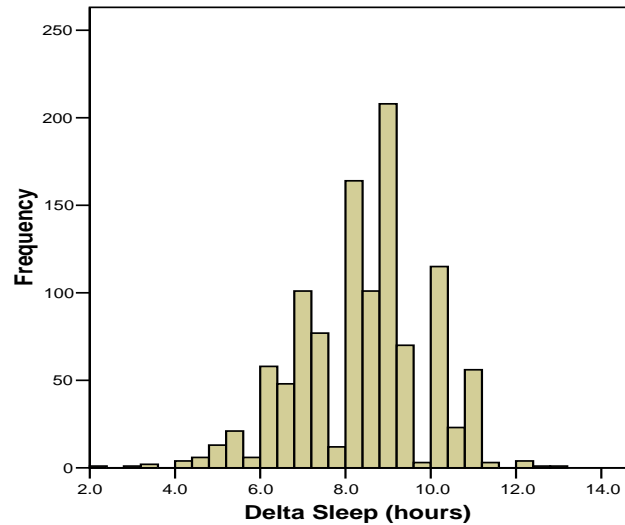


Figure 13. Frequency diagrams of Delta Sleep for Cleaned cadets subset (n=1099) from pre-CBT survey, 2003.

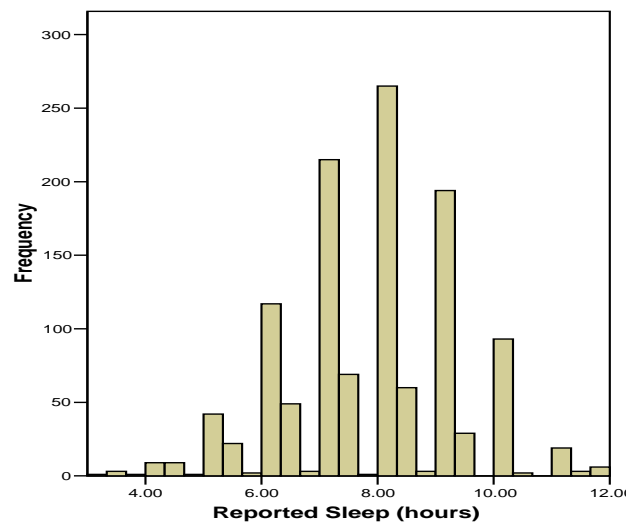


Figure 14. Frequency diagrams of Reported Sleep for Cleaned cadets subset (n=1072) from pre-CBT survey, 2003.

### 3. Reported Bedtime

Participants were asked to report their average bedtime in the 30 days prior to CBT. For those individuals answering this question,  $\bar{x}=12:20$  a.m., s.d.= 1.42 hours. For the dataset including only Cleaned cadets,  $\bar{x}=12:23$  a.m., s.d.= 1.35 hours. The two distributions can be seen in Figure 15. Some of the participants reported very late bedtimes and correspondingly late wake-up times. This sleep schedule was considered possible since many of the participants were on summer break.

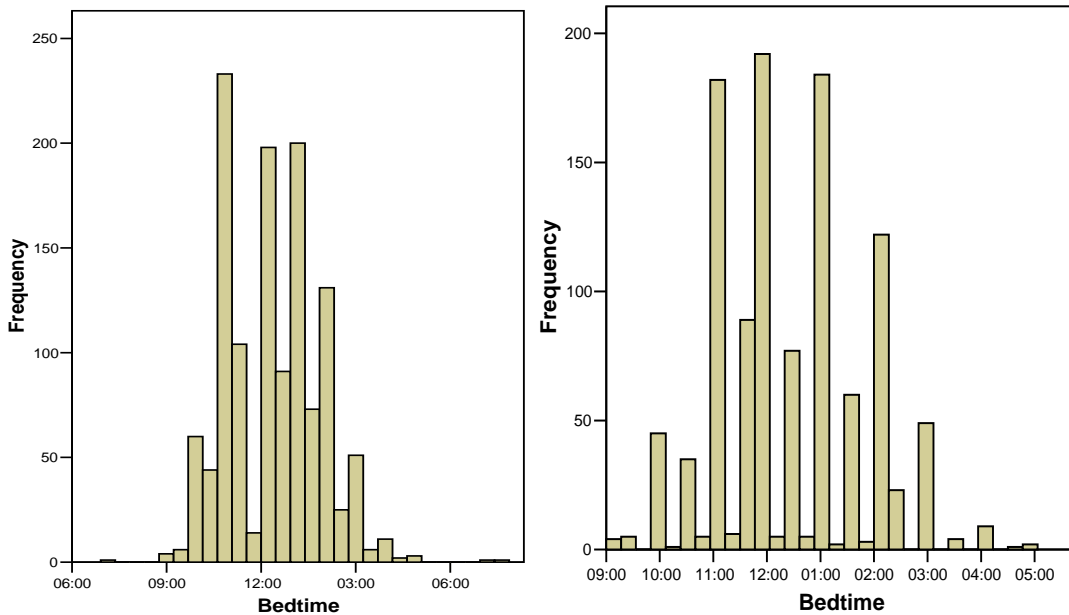


Figure 15. Distribution of reported bedtimes of Cleaned cadets subset (n=1109), from the pre-CBT survey, 2003.

### 4. Wake-up Time

Participants were asked to report their average wake-up time in the 30 days prior to reporting for CBT. For those individuals who responded,  $\bar{x}=8:50$  a.m., s.d.= 1.88 hours. For the Cleaned cadets subset,  $\bar{x}=8:44$  a.m., s.d.= 1.78 hours, and is right skewed, as seen in Figure 16.

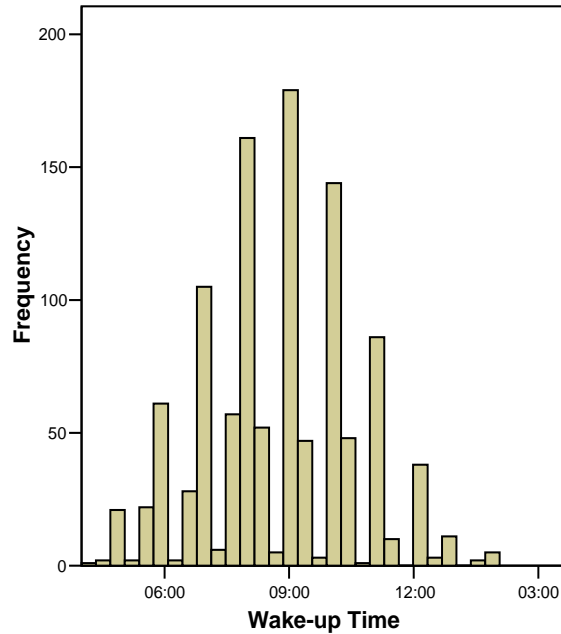


Figure 16. Distribution of reported wake-up times of the Cleaned cadets subset (n=1102) from the pre-CBT survey, 2003.

## 5. Recruited Athletes

The survey asked if the cadet was an actively recruited athlete for admission to USMA. Of 1218 individuals who answered this question, 19.2% answered “Yes.” Of these recruited athletes, the highest numbers of cadets were recruited for football, or 20.3%, followed by soccer and track, which each had about 10% of the recruits.

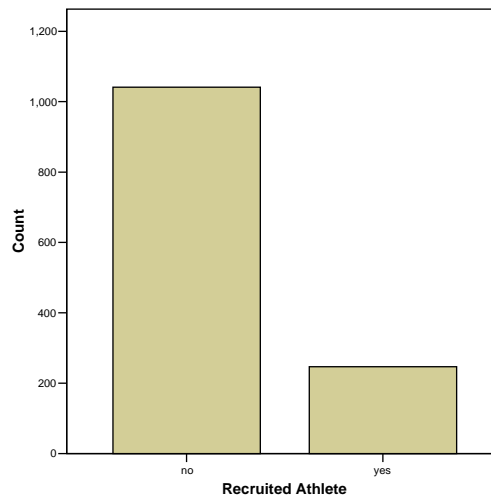


Figure 17. Frequency chart for the reported number of recruited and non-recruited athletes (n=1218). From pre-CBT survey, 2003.

## **6. Tobacco**

Of 1239 responses, 230 of the cadets (18.5%) claimed to use a form of tobacco. The most common form of tobacco use reported was smokeless tobacco. A total of 51 cadets appeared to be regular smokeless tobacco users. A closer inspection revealed that 134 or 10.8% of the population actually smoked cigarettes or cigars, or used some type of smokeless product on a regular basis. The other individuals were infrequent users (e.g., smoked one cigarette one time). Individuals were considered tobacco users if they reported using at least 1 cigar a week, 1 cigarette per day, or 1 smokeless tobacco product per day.

## **7. Caffeine**

Participants were asked, “During the past month, how many caffeinated beverages did you consume in a 24 hour period in each category?” The choices were 8 ounces of coffee, 12 ounces of soda, or 8 ounces of tea. Many of the cadets did not respond. These incomplete responses were omitted from the descriptive statistics.

### ***a. Coffee***

Participants reported drinking an average of .38 cups of coffee per day in the 30 days prior to CBT (s.d.  $\approx$  1 cup). The data were right skewed, as shown in Figure 18. The maximum number of reported cups was one cadet at 10 cups of coffee per day. Generally speaking, the cadets were not coffee drinkers before they entered USMA.



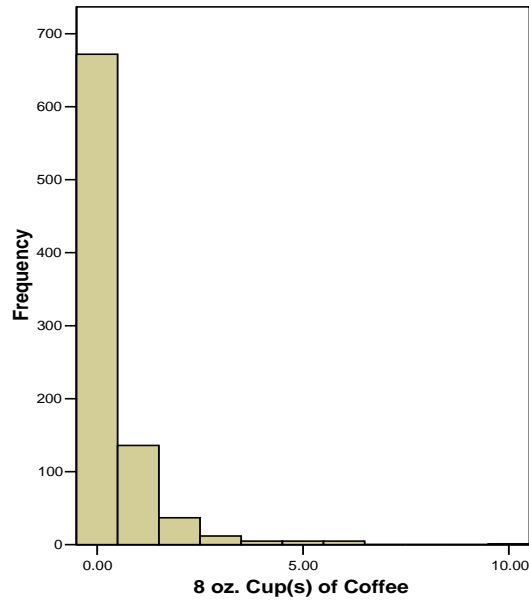


Figure 18. Frequency graph for the reported number of cups of coffee consumed on average in one day (n = 873). From pre-CBT survey, 2003.

***b. Soda***

Participants reported drinking an average of 1.5 cans of soda per day in the 30 days before CBT (s.d. = 2.3 cans). The median and mode response was 1 can of soda. One cadet reported drinking 30 cans, while another reported 20 cans per day. The two records were returned, although they are subject to question.

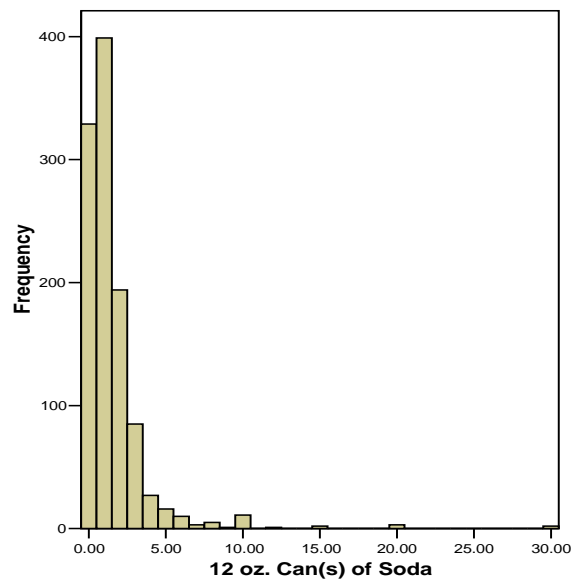


Figure 19. Frequency graph for the reported number of 12 ounce cans of soda consumed on average in one day (n=1088). From pre-CBT survey, 2003.

**c. Tea**

Participants reported drinking an average of .84 cups of tea per day in the 30 days before CBT (s.d. = 1.7 cups). The distribution of tea consumption was right skewed, as seen in Figure 20. The maximum number of reported cups was 18, also a questionable observation.

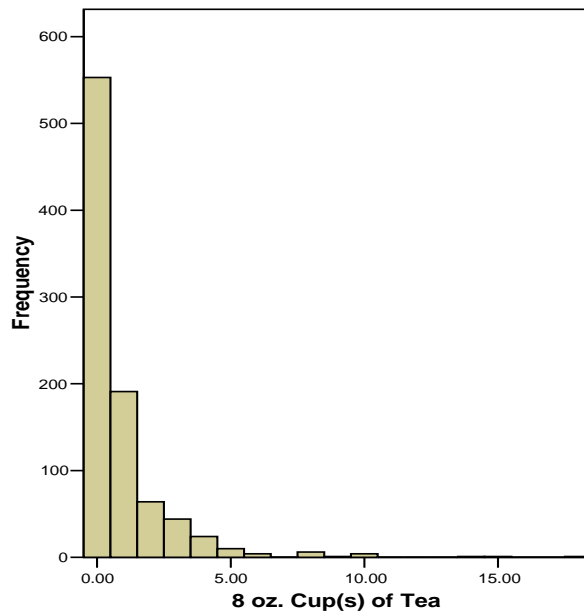


Figure 20. Frequency graph for the reported number of 8 ounce cups of tea consumed on average in one day (n= 904). From the pre-CBT survey, 2003.

**8. Correlations of the pre-CBT Survey**

Additional data about the cadets were gathered electronically through the USMA Admissions Office and Office of Institutional Research. These data included the variables race, gender, scores on college entrance exams, high school class rank, and 1<sup>st</sup> Term Academic, Military, and Physical program scores. For an entire list complete with definitions, see Appendix B. Using pair-wise correlations, these variables were compared to the variables from the pre-CBT survey. All comparisons were also made using the Cleaned sub-sample. Three pairs of variables had correlations  $r > |0.10|$ : bedtime and high school class rank ( $r=0.112$ ), bedtime and Whole Candidate Score ( $r = -0.111$ ), and bedtime and CEER score ( $r=-0.110$ ). The null hypothesis of zero correlation against a two-sided hypothesis is rejected at .01 level of significance for all three of these pairs of variables. Because sample sizes are so large

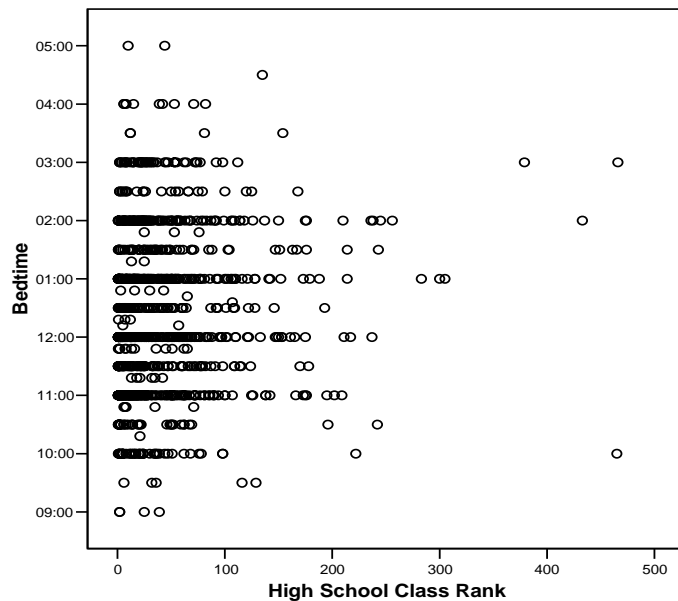


Figure 21. Scatterplot of bedtime versus high school class rank. From pre-CBT survey (Cleaned cadets,  $n=1107$ ) and data from the Admission Office and Office of Institutional Research at USMA, 2003. ( $r=0.104$ ,  $p=0.001$ ).

## 9. Differences in Sleep Between Groups

Using the large sample size from the pre-CBT survey, independent-sample z-tests with unequal variances were used to explore whether or not there was a gender difference in the sleeping habits of the future cadets. The test showed a difference in the reported bedtimes ( $n_{\text{males}}=1056$ ,  $n_{\text{females}}=203$ ,  $z=2.53$ ,  $p=0.014$ ) and wake-up times ( $n_{\text{males}}=1049$ ,  $n_{\text{females}}=203$ ,  $z=3.71$ ,  $p<0.001$ ) between males and females, as shown in Table 3. See boxplots in Figure 22. However, there were no significant differences between Delta Sleep or Reported Sleep between men and women. See Figure 26 in Appendix C for the detailed output.

	<i>Bedtime</i>	<i>Wake-up time</i>
<b>Males</b>	12:26 a.m.	8:47 a.m.
<b>Females</b>	12:08 a.m.	8:25 a.m.

Table 3. Table of reported average bedtimes and wake-up times for cadets 30 days prior to CBT, from pre-CBT survey, 2003.

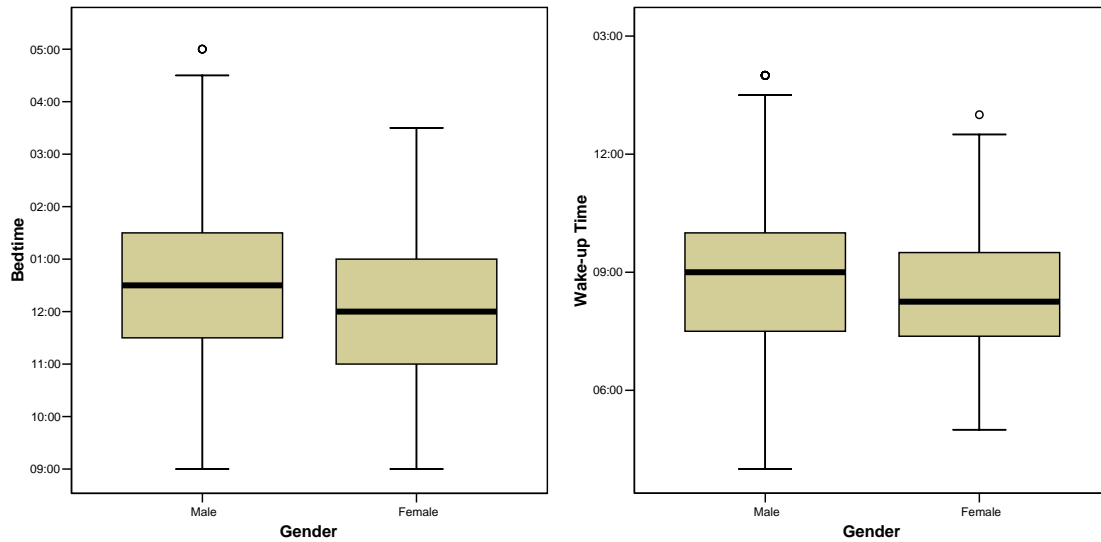


Figure 22. Boxplots of bedtimes ( $n_{\text{males}}=931$ ,  $n_{\text{females}}=179$ ) and wake-up times ( $n_{\text{males}}=923$ ,  $n_{\text{females}}=179$ ) by gender (Cleaned cadets), from pre-CBT survey, 2003. On average, as compared to females, males reported both a later mean bedtime and wake-up time.

Using the Cleaned cadets sample ( $n=1103$ ), independent z-tests showed that there was a difference ( $p=.046$ ) between the wake-up time of the recruited athletes and non-recruited athletes in high school. Recruited athletes reported waking up at 8:57 a.m. on average, while their peers reported 8:41 a.m. Other aspects of sleep were not significant. See Appendix C, Figure 31.

Using the Cleaned cadets sample, independent z-tests showed that self-reported tobacco users also reported later bedtimes ( $p<0.001$ ) and wake-up times ( $p<0.001$ ). See Table 4 for average times and Figure 23 for comparative boxplots. For the results of the corresponding t-tests, see Appendix C, Figure 32.

	<i>Bedtime</i>	<i>Wake-up time</i>
<b><i>Tobacco</i></b>	12:47 a.m.	9:10 a.m.
<b><i>No tobacco</i></b>	12:17 a.m.	8:36 a.m.

Table 4. Table of reported average bedtimes ( $n=1083$ ) and wake-up times ( $n=1080$ ) of those who reported their tobacco use for the 30 days prior to reporting to CBT, from the pre-CBT survey, 2003.

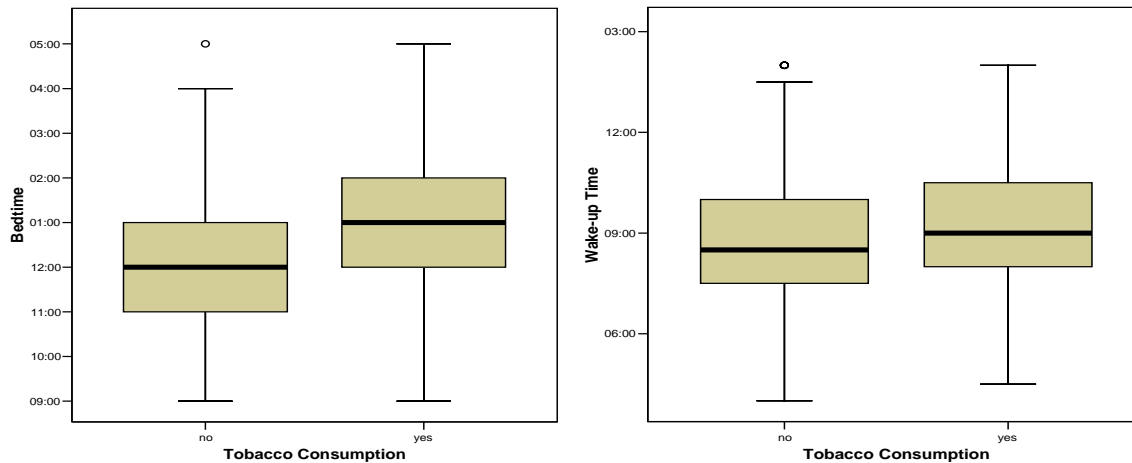


Figure 23. Boxplots of bedtimes (n=1083) and wake-up times (n=1080) by tobacco use (Cleaned cadets), from pre-CBT survey, 2003. On average, users reported both a later mean bedtime and wake-up time.

Independent z-tests showed that self-reported caffeine users also reported a later bedtime ( $p=0.028$ ) and wakeup time ( $p=0.020$ ). See boxplots and tables of average bedtime and wake-up time by caffeine use in Figure 24 and Table 5. For the results and corresponding z-tests, see Appendix C, Figure 33.

	<i>Bedtime</i>	<i>Wake-up time</i>
<b>Caffeine</b>	12:27 a.m.	8:50 a.m.
<b>No caffeine</b>	12:15 a.m.	8:35 a.m.

Table 5. Table of reported average bedtimes (n= 991) and wakeup times (n=991) of those who reported their caffeine use for the 30 days prior to reporting to CBT, from the pre-CBT survey, 2003.

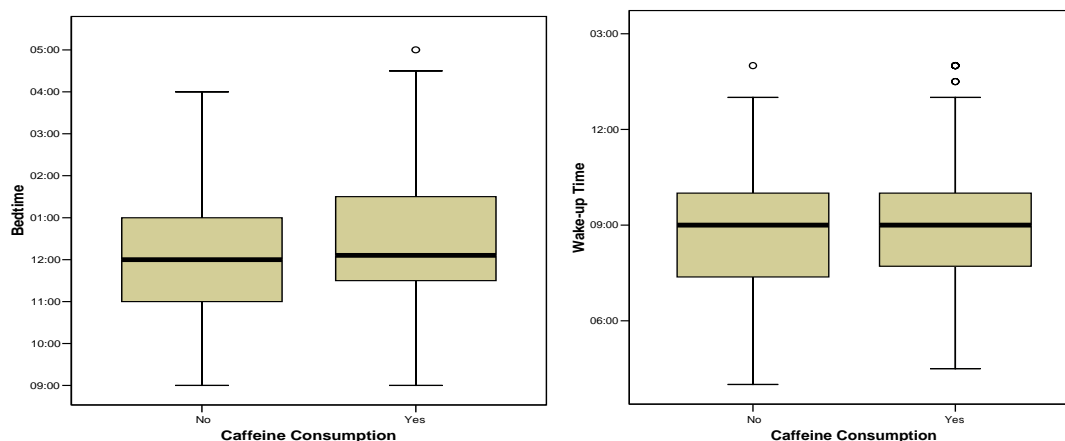


Figure 24. Boxplots of bedtime (n=991) and wake-up time (n=991) by caffeine use (Cleaned cadets), from pre-CBT survey, 2003.

## **B. FALL 2003 SLEEP DATA**

Using the actigraphy data (n=73) collected during the Fall 2003 semester, paired correlations were computed among sleep variables, fall academic performance variables, pre-CBT survey variables, and additional variables collected from the Admissions Office and Office of Institutional Research at USMA. Comparisons were also made using a subset of n=69 cadets. The only significant linear dependence within either group was between weekend bedtimes and first semester academic performance ( $r = -0.271$ ,  $p = 0.020$ ). For a full report, see Appendix G. Large sample z-tests showed there was no significant difference in the sleeping habits between gender for the Fall sleep data.

Paired large sample z-tests revealed that there was a significant difference between mean Reported Sleep ( $z = 14.8$ ,  $p < 0.001$ ) and Delta Sleep ( $z = 18.6$ ,  $p < 0.001$ ) in the pre-CBT survey and sleep that the cadets received in the Fall of 2003. Cadets were getting significantly less sleep at USMA than they reported getting 30 days before they reported to CBT. For the Cleaned subsample, mean Delta Sleep was roughly 504 minutes, while Reported Sleep averaged 475 minutes. During the school year, actigraphy data yielded an overall average of 321 minutes, categorized by school night (293 minutes) and non-school night (394 minutes). See Appendix H for the full results of these tests.

## **C. MORNINGNESS-EVENINGNESS CHRONOTYPES**

A question on the pre-CBT survey addressed morningness-eveningness chronotypes of incoming cadets. The question read:

One sometimes hears about "feeling best in the morning" or "feeling best in the evening" types of people. Which do you consider yourself?

- a. Definitely a "morning" type (Lark)
- b. More a "morning" than an "evening" type (more Lark than Owl)
- c. Neither (Robin)
- d. More an "evening" than a "morning" type (more Owl than Lark)
- e. Definitely an "evening" type (Owl)

Distribution of answers to this question can be seen in Figure 25.

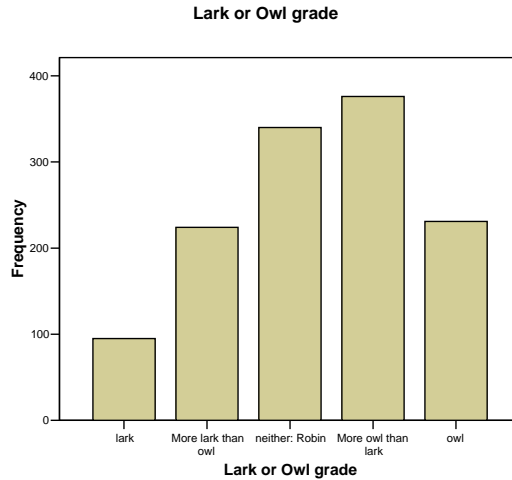


Figure 25. Distribution of self-reported morningness-eveningness chronotype.

Lark = morning preference; Owl = evening preference; Robin = neither.

The responses were pooled into two groups: owl or non-owl. That is, those individuals who indicated that they were owls (answers “d” or “e”) were grouped separately from robins and larks (answers “a,” “b,” or “c”). As expected, there was a high correlation ( $p < 0.001$ ) between morningness-eveningness and self-reported pre-CBT bedtimes and wake-up times. Using this grouping, 47.9% of incoming cadets were classified as owls, while 52.1% were classified as non-owls.

Attrition rates for these two groups (owls and non-owls) were compared. Of the 1253 cadets for which there are survey data, 125 left or were separated from USMA, as of February 2004. Of these individuals, the majority of the attrites were owls. See attrition distribution in Table 6. Using a test of proportion, there is a significant difference in the rate of attrition between owls and larks ( $z = 2.66$ ,  $p = 0.0039$ ).

	Separated	Active	Total
Non-Owl	51	602	653
Owl	74	526	600
Total	125	1128	1253

Table 6. Cadet attrition by morningness-eveningness chronotype.

See Appendix I. Owls were overrepresented in the group of cadets who attrited (i.e., 74 or 59.2% were owls while 51 or 40.8% were non-owls).

Using grades for academic, military, and physical performance from the Fall semester, the success of cadets was assessed in terms of their morningness-eveningness chronotype. Using large sample z-tests for proportions, there is a significant difference between Fall performance in these grades and lark and owl chronotypes. The z-tests results are: Fall term academic quality point average ( $z=3.92$ ,  $p<0.001$ ), military program score ( $z=5.169$ ,  $p<0.001$ ), and physical program score ( $z=3.295$ ,  $p=0.001$ ).



## **V. RECOMMENDATIONS AND CONCLUSIONS**

### **A. PRE-SURVEY**

A portion of the pre-CBT survey was administered manually, making it vulnerable to transcription errors when the data were later entered into a spreadsheet. In addition, there was difficulty merging this manually entered data with the electronically scanned data from the USMA Admissions Office and Office of Institutional Research and with the Fall semester performance and sleep data. Future surveys should be given online if at all possible, with the requirement that all fields must be filled out. Surveys could be administered under the cadet's private login name to ensure that there is no confusion about the participant's identity.

The pre-CBT survey contained several questions from the PSQI, a clinical self-rated questionnaire used to assess the quality of sleep of the participant. However, only part of the entire PSQI was extracted and administered in the pre-CBT survey. The scoring method of the PSQI requires all the questions to be answered in order to accurately measure sleep quality and disturbances over a one-month interval. This issue made analysis more challenging. Other than describing the frequency of the answers in this portion of the survey, few conclusions could be drawn. The cadets could not be divided into "good" and "poor" sleepers with any proven measure of accuracy.

The pre-CBT survey also contained an abridged morningness-eveningness questionnaire to help determine a cadet's circadian or diurnal preference. Only the question that directly asked the cadet to report morningness-eveningness was considered in this thesis. In order to determine a more precise classification for each cadet, it is suggested that a validated morningness-eveningness survey, such as the Horne-Ostberg survey, be administered to confirm the findings of this study.

The questions in the survey specifically asked the cadets about their behavior "During the past month..." (see Appendix A). This insight into a cadet's life before West Point is very limited in scope. For instance, some cadets graduated from high school only a few hours or days before the beginning of CBT, while other cadets finished high school more than a month before beginning CBT. Depending on their school and work

status, responses for this 30 day period may reflect a tremendous amount of extraneous variability in the data. A cadet's sleeping habits may have changed considerably from the previous academic year compared to a summer break period. Even the questions that address nicotine and caffeine use refer to a transient period in the cadet's life, which might have been different from the norm. The survey should have posed the questions in terms of the cadet's normal routine or collected data on what activities the cadet was doing over that 30 day period.

## **B. ACTIGRAPHY**

One concern with the actigraphy data was initiating a systematic approach to track cadet sleep that would enable them to remain anonymous. It was important to this study to have an accurate match between a cadet's sleep data and their demographic information. However, when handling the downloaded data, it was extremely difficult to identify to whom the data belonged, because of an inconsistency in the file naming convention. For future actigraphy collection and ease of data handling, each file name should include a clear identifying feature, such as birthday or the last four digits of social security number, in order to avoid unnecessary confusion.

Using the Actiware software available at the time of the study, analyzing the actigraphy data was problematic. Actiware 3.4 had the capability of determining sleep onset and offset, and total contiguous nighttime sleep, but had a separate program to address daytime naps. This drawback made determination of total net daily sleep difficult to obtain. This inadequacy in the Actiware software complicated many of this study's primary research questions, which addressed the correlation between academic performance and total sleep. As soon as the updated version of the Actiware program is available, it is recommended that new comparisons be made between average total daily sleep and performance.

## **C. ACTIVITY LOGS**

The activity logs would have been a great complement to the actigraphy data if they had been filled out more consistently. While some of the cadets thoroughly entered their daily routine, others neglected to even return their activity logs. In the future, it may

be beneficial to simplify the task of recording activity by consolidating the choices. For example, TV or DVD watching, video games, or Internet can all be summarized under a single category of “Entertainment.”

In addition, because the activity logs were recorded by hand, transcribing these logs introduced another possibility for error. Some of the handwriting was illegible. Future activity logs might be better managed online or through PDAs, perhaps in the form of a survey that is administered every day.

#### **D. TIME FRAME**

The cadets were issued their actiwatches on or around 17 November 2003. The first week may have been considered a normal week of school. However the following week was interrupted by a shortened academic day on Wednesday 26 November, which began a 4 day Thanksgiving holiday weekend, and which terminated on Sunday, 30 November. The week following Thanksgiving break is known as “ARMY/NAVY” week, because it is the week immediately preceding the traditional Army Navy Football game. The cadets are expected to meet their normal academic and military obligations, but are also busy with school-spirit activities. Therefore, this week does not represent an “average” week in the life of a cadet. Cadets were all required to attend the Army Navy Football game, in Philadelphia, PA, on 2 December, a day when reveille wakes them up at 4 a.m. Shortly after this weekend, the regular academic period ends, and their final exam period begins. During final exam periods, cadets do not have classes, and their military obligations are curbed to allow for extra study time. The cadets returned their actiwatches sometime after exams, before they went home for Christmas break.

In summary, the cadets were issued their actiwatches during an unusually busy month of the fall academic semester, which may not be representative of the normal academic year. In the future, it would be preferable to distribute the actiwatches at the end of September or beginning of October, to obtain a more accurate representation of cadet sleep during the academic year. This time of year does not include finals, or any strange military obligations, as does both the beginning and end of the semester.

#### **D. NAP ANALYSIS**

Conclusions about the relationship between sleep and grades were only based on contiguous nighttime sleep. As can be seen in the activity logs, many of the cadets took naps sporadically during the course of a week. Some of these reported naps exceeded 2 hours in length. Perhaps average net sleep for a 24-hour period is correlated with academic performance. Once the software is available, actigraphy data can be used to re-test this hypothesis.

#### **E. FUTURE SURVEY QUESTIONS**

In the future, proposed questions might ask about the number of “sick call” visits made, or a report about the number and severity of any illness had during the semester. Another point to be addressed is the variation in mood states of each cadet throughout the course of a semester.

#### **F. SUMMARY**

This study reports the initial findings of a four-year longitudinal study undertaken to assess the amount of sleep received by cadets at the United States Military Academy. Actigraphy data revealed that cadets received much less nighttime sleep (not including naps) during the Fall academic semester than they reported receiving in the 30 days before CBT.

The need for sleep is a combination of the circadian sleep cycle and the homeostatic sleep drive, which builds with increasing time spent awake. A phase shift in this circadian cycle occurs in adolescence. The highest sleep efficiency can be achieved when cadets sleep during a time frame more in harmony with their circadian clock, which is set to generally go to bed later and wake up later than adults. In a study done at the U.S. Navy Great Lakes Recruit Training Center, recruits were allowed the exact amount of time asleep – 8 hours, but the bedtimes were at either 9:00 pm or 10:00 pm. When the group went to bed an hour later, they actually got 22 extra minutes of sleep on average (Miller, Baldus, Coard, Sanchez & Redmond, 2003).

At USMA, cadets wake-up at or before dawn and adhere to a strict schedule, one for which it may be difficult to adjust. Attrition rate in the first year is higher for those

who reported being owls than for those who reported being larks. In addition, military, physical, and academic grades are significantly different depending on diurnal preference. Owls seem to be at an immediate disadvantage. Although morningness-eveningness is not the sole determinant of success or failure at USMA, it is a contributing factor to cadet performance.

In conclusion, cadets at USMA were undoubtedly getting less than the recommended amount of sleep. It would be beneficial to educate the Brigade to alert them to the signs and symptoms of the consequences of sleep deprivation. As future leaders in an Army populated primarily by young people, they need to know the biological implications of sleep deprivation—factors that cannot be cheated or outsmarted by will power. In addition to implementing a sleep education program, first year cadets might benefit from a “lights out” policy – one that would be enforced through the early morning hours until reveille.

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## APPENDIX A. PRE-CBT SURVEY



### USMA Cadet Sleep Study



#### INTRODUCTION:

The following two-part survey is designed to assess your sleep patterns prior to reporting to the United States Military Academy. **PART ONE** consists of multiple choice questions. Your answers will be recorded on the accompanying USMA General Purpose Answer Sheet. **PART TWO** consists of fill-in-the-blank questions. Your answers to these questions will be recorded on this questionnaire in the spaces provided.

#### INSTRUCTIONS for Part One:

Answer the following questions on the accompanying USMA General Purpose Answer Sheet.

**Name.** Enter your name on the USMA General Purpose Answer Sheet in the space provided and fill in the circles below each letter.

**Social Security Number (SSAN).** Enter your SSAN on the USMA General Purpose Answer Sheet in the space provided and fill in the circles below each number.

1. Gender
  - a. Male
  - b. Female

Questions 2 - 10 relate to your usual sleep patterns during the last month prior to arriving at USMA.. Your answers should indicate the most accurate reply for the majority of days and nights in the past month only.

<b>During the past month</b> , how often have you had trouble sleeping because you....	Not during past month	Less than once a week	Once or twice a week	Three or more times a week
2. Cannot get to sleep within 30 minutes?	a	b	c	d
3. Wake up in middle of the night or early in morning?	a	b	c	d
4. Have to get up to use the bathroom?	a	b	c	d
5. Cannot breathe comfortably?	a	b	c	d
6. Cough or snore loudly?	a	b	c	d
7. Feel too cold?	a	b	c	d
8. Feel too hot?	a	b	c	d
9. Had bad dreams?	a	b	c	d
10. Have pain?	a	b	c	d
11. <b>During the past month</b> , how often have you taken medicine to help you sleep (prescribed or 'over the counter')?	a	b	c	d
12. <b>During the past month</b> , how often have you had trouble staying awake while driving, eating, or engaging in social activity?	a	b	c	d

13. *During the past month*, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

- a. No problem at all
- b. Only a very slight problem
- c. Somewhat of a problem
- d. A very big problem

14. *During the past month*, how would you rate your sleep quality overall?

- a. Very good
- b. Fairly good
- c. Neither good nor bad
- d. Fairly bad
- e. Very bad

15. *During your last vacation*, how often did you get up later than planned or have difficulty getting ready on time even though you went to bed at your regular time?

- a. It never happened.
- b. It happened once.
- c. It happened two times.
- d. It happened three or more times.

16. When you have no commitments the next day, at what time do you go to bed compared with your usual time?

- a. Seldom or never later
- b. Not more than one hour later
- c. Between one and two hours later
- d. More than two hours later

17. Suppose that you have decided to exercise twice a week with a friend. The only time your friend can make it is from 7:00 a.m. to 8:00 a.m., twice a week. Assume you decide to go at these times. Taking into account how you usually feel in the morning, how would you do?

- a. Very well
- b. Well
- c. Same as any other time period
- d. Poorly
- e. Very Poorly

18. At what time in the evening do you usually start feeling tired and in need of sleep?

- a. 8:00 p.m. – 9:30 p.m.
- b. 9:31 p.m. – 10:45 p.m.
- c. 10:46 p.m. – 12:30 a.m.
- d. 12:31 a.m. – 1:45 a.m.
- e. 1:46 a.m. – 3:00 a.m.

19. Suppose that you were able to choose your own working hours. Assume that your job was interesting and paid according to results. Which one of the following 3-hour blocks would be your **most preferred** work time?

- a. 4:00 a.m. – 7:00 a.m.
- b. 7:00 a.m. – 10:00 a.m.
- c. 11:00 a.m. – 2:00 p.m.
- d. 4:00 p.m. – 7:00 p.m.
- e. 9:00 p.m. – 12:00 Midnight.

20. One sometimes hears about "feeling best in the morning" or "feeling best in the evening" types of people. Which do you consider yourself?

- a. Definitely a "morning" type
- b. More a "morning" than an "evening" type
- c. Neither a "morning" nor an "evening" type
- d. More an "evening" than a "morning" type
- e. Definitely an "evening" type



**INSTRUCTIONS for Part TWO:**

Answer the following questions in the spaces provided below.

Name  
 Last First MI

Social Security Number

Date of Birth  
 MM/DD/YY (i.e., 03/27/85)

Height (in inches)  
 65

Weight (in lbs)  
 155

Date you began travel to West Point (MM/DD (i.e., 06/29)) 06/29

Location from which travel began (state or country) NEW JERSEY

Were you recruited to play a sport at West Point? (Y/N) N

If so, which sport?

The following instructions relate to your usual sleep patterns during the last month prior to arriving at USMA. Your answers should indicate the most accurate reply for the majority of days and nights in the past month only.

21. During the past month, what time have you usually gone to bed at night? 1:00 AM (time)

22. During the past month, how long has it usually taken you to fall asleep each night? 30 (minutes)

23. During the past month, what time have you usually gotten up? 7:00 AM (time)

24. During the past month, how many hours of actual sleep did you get at night? 6 (number of hours)  
 (This may be different than the number of hours you spent in bed)

25. During the past month did you use any tobacco products? (Y/N) Y

If yes, what? Smokeless (Skaal, Dip) How much and how often? One Pinch, once in the last month

26. During the past month, how many caffeinated beverages did you consume in an average 24-hour period in each category?

Coffee (8 oz cups): 0 Caffeinated Soda (12 oz cans): 6 Tea, hot or iced (8 oz cups or glasses): 10

27. List any medications (either over-the-counter or prescription) that you are currently taking:

none

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## **APPENDIX B. SCORING SHEET FOR ADMISSIONS DATA**

### **POTENTIAL CANDIDATE MASTER FILE CLASS OF 88-UP**

#### **WHOLE-CANDIDATE-SCORE (WCS)**

A COMPOSITE SCORE INDICATING AN INDIVIDUAL'S TOTAL PREDICTED POTENTIAL FOR ADMISSION TO USMA. COMPUTED IWA THE USMA ACADEMIC BOARD DIRECTIVE ON THE QUALIFICATION OF CANDIDATES FOR ADMISSION TO USMA.

RANGE 1840 – 7940

#### **COLLEGE-ENTRANCE-EXAM-RANK**

A WEIGHTED MEAN OF THE INDIVIDUAL'S COLLEGE BOARD SCORES AND HIGH SCHOOL CLASS RANK SCORE. MAY BE COMPUTED FROM: PRELIMINARY SCHOLASTIC APTITUDE TEST (SAT), AMERICAN COLLEGE TEST (ACT). THE SCORE IS INDEPENDENT BY THE CEER-SOURCE-FLAG

#### **ACADEMIC-SUPPLEMENT-SCORE**

#### **PHYSICAL-APTITUDE-EXAM-SCORE**

A COMPOSITE SCORE ON THE PHYSICAL APTITUDE EXAM DERIVED BY COMPARING EACH OF THE COMPONENT SCORES TO A TRANSLATION TABLE, THEN SUMMING THE TRANSLATION SCORES.

RANGE 200-800

#### **LEADERSHIP-POTENTIAL-SCORE**

A NUMERICAL EVALUATION OF AN INDIVIDUAL'S POTENTIAL AS A LEADER. COMPUTED IAW THE USMA ACADEMIC BOARD DIRECTIVE ON THE QUALIFICATION OF CANDIDATES FOR ADMISSION TO USMA.

RANGE 200-800

**WCS CALCULATION:**

$$\begin{aligned} \text{WCS:} & \quad (6 \times \text{CEER}) + (3 \times \text{CLS}) + (\text{PAE SCORE}) \\ \text{CEER:} & \quad (.364 \times \text{HSR}) + (.269 \times \text{SATV}) + (.432 \times \text{SATM}) - 48 \\ \text{ACEER:} & \quad (.219 \times \text{HSR}) + (9.43 \times \text{ACTM}) + (4.62 \times \text{ACTE}) + (.45 \times \text{ACTS}) + (4.01 \times \text{ACTR}) - 41.5 \\ \text{HSR:} & \quad ((2 \times \text{HS STANDING}) - 1) / (2 \times \text{CLASS SIZE}) \\ \text{CLS OR LPS:} & \quad (\text{EX} + \text{AT} + \text{FAS}) / 3 \\ \text{APS:} & \quad (.001926 \times \text{HSR}) + (.002283 \times \text{SATM}) + (.001421 \times \text{SATV}) - .6865 \\ \text{HPA NEW SAT:} & \quad (.001070 \times \text{SATM}) + (.04132 \times \text{SATV}) + (.002035 \times \text{HSR}) - 1.390 \\ \text{HPA ACT:} & \quad (.001249 \times \text{HSR}) + (.04132 \times \text{ACTE}) + (.01087 \times \text{ACTM}) + (.02944 \times \text{ACTSR}) - .3257 \\ \text{MSE NEW SAT:} & \quad (.004884 \times \text{SATM}) - (.000093 \times \text{SATV}) + (.002477 \times \text{HRS}) - 1.652 \\ \text{MSE ACT:} & \quad (.002004 \times \text{HSR}) + (.1487 \times \text{ACTM}) + (.03713 \times \text{ACTSR}) + (.02022 \times \text{ACTR}) - (.06084 \times \text{ACTM}(\text{GT})) - 2.2873 \end{aligned}$$

**RISK LEVELS AND REQUIRED CHECKS:****RISK LEVEL (CHECKS REQUIRED)**

SATV < 560	CLS < 450
SATM < 560	PAE < 420
ACTE < 23	FAS < 525
ACTM < 24	WCS < 5200
ACTR < 24	HPA < 2.10
ACTS < 23	MSE < 2.10
CEER / ACEER < 520	APS < 2.15

**DEFINITIONS:**

LEADER: CLS  $\geq$  650  
 SCHOLAR: CEER OR ACEER  $\geq$  650

**ESTIMATES:**

$$\text{FAS} = 600$$

$$\text{PAE} = (\text{AT} + 400) / 2$$

**Academic Quality Point Average (AQPA):**

Letter grade (converted to numeric) \* credit hours / by total credit hours

(EV203) 3.00(credit hrs) \* 3.00 (ltr grd B) +

(LW403) 3.50 \* 3.00 (B) +

(SE388) 3.00 \* 4.00 (A) +

(PE430) .50 \* 3.67 (A-) +

Divide by total credit hrs 10.00 = 3.334

**Academic Program Score (APS):**

Letter grade (converted to numeric) \* credit hours / by total credit hours

(The APS excludes the Military Science (MS) and Physical Education (PE) courses)

Same as above excluding PE 430:

(EV203) 3.00(credit hrs) \* 3.00 (ltr grd B) +

(LW403) 3.50 \* 3.00 (B) +

(SE388) 3.00 \* 4.00 (A) +

Divide by total credit hrs 9.50 = 3.316

**Military Program Score (MPS):**

Letter grade (converted to numeric) \* the activity weight / the total activity weight

MD100 2.00(weight) \* 4.00 (ltr grd A) +

MD101 2.50 \* 3.67 (A-) +

MS102 6.00 \* 4.33 (A+) +

MD200 8.00 \* 4.00 (A) +

Divided by total weight 18.50 = 4.062

**Cadet Performance Score (CPS):**

Standardize scores:

APS minus class mean of APS / class Std. Dev. ( 3.004 - 2.968) / .471

MPS minus class mean of MPS / class Std. Dev. ( 3.003 - 3.274) / .241

PPS minus class mean of PPS / class Std. Dev. ( 3.240 - 3.128) / .301

Apply weights:

(.55 (std APS)) + (.30(std MPS)) + (.15(std PPS)) (.55 \* .07431) + (.30 \* -1.1245) + (.15 \* .3721) = -0.24066

Convert above score to 4.0 scale transforming into a normal distribution with a mean of 2.8 and a standard deviation of 0.40:

$$\text{CPS} = (0.40) * \frac{[\text{STD CPS}]}{[\text{CPS Std Dev}]} + 2.80$$

$$0.40 * (-0.24066 / .8119) + 2.8$$

$$\text{CPS} = 2.681$$

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## APPENDIX C. OUTPUT FOR T-TEST

	<b>z</b>	<b>Sig.(2-tail)</b>
<b>Time to bed</b>	2.533	.012
<b>Wake-up time</b>	3.716	.000
<b>Delta Hrs</b>	2.027	.044
<b>Reported Hrs</b>	1.435	.153

Figure 26. Large sample test for differences in population means between women and men based on independent samples with different variables. From pre-CBT survey, 2003. Original dataset.

	<b>z</b>	<b>Sig.(2-tail)</b>
<b>Time to bed</b>	-.921	.357
<b>Wake-up time</b>	-1.757	.080
<b>Delta Hrs</b>	-.972	.332
<b>Reported Hrs</b>	.077	.938

Figure 27. Large sample test for differences in population means between recruited and non-recruited athletes based on independent samples with different variables. From pre-CBT survey, 2003. Original dataset.

	<b>z</b>	<b>Sig.(2-tail)</b>
<b>Time to bed</b>	-4.993	.000
<b>Wake-up time</b>	-3.333	.001
<b>Delta Hrs</b>	.418	.677
<b>Reported Hrs</b>	-1.244	.214

Figure 28. Large sample test for differences in population means between self-reported tobacco users, and non-users based on independent samples with different variables. From pre-CBT survey, 2003. Original dataset.

	<b>z</b>	<b>Sig.(2-tail)</b>
<b>Time to bed</b>	-1.798	.072
<b>Wake-up time</b>	-2.864	.004
<b>Delta Hrs</b>	-1.659	.097
<b>Reported Hrs</b>	-.248	.804

Figure 29. Large sample test for differences in population means between self-reported caffeine users, and non-users based on independent samples with different variables. From pre-CBT survey, 2003. Original dataset.

	<b>z</b>	<b>Sig.(2-tail)</b>
<b>Time to bed</b>	2.549	.011
<b>Wake-up time</b>	2.767	.006
<b>Delta Hrs</b>	.906	.366
<b>Reported Hrs</b>	1.256	.210

Figure 30. Large sample test for differences in population means between women and men based on independent samples with different variables. From pre-CBT survey, 2003. Cleaned cadets dataset.

	<b>z</b>	<b>Sig.(2-tail)</b>
<b>Time to bed</b>	-1.854	.065
<b>Wake-up time</b>	-2.015	.045
<b>Delta Hrs</b>	-.642	.521
<b>Reported Hrs</b>	-.649	.517

Figure 31. Large sample test for differences in population means between recruited and non-recruited athletes based on independent samples with different variables. From pre-CBT survey, 2003. Cleaned cadets dataset.

	<b>z</b>	<b>Sig.(2-tail)</b>
<b>Time to bed</b>	-4.922	.000
<b>Wake-up time</b>	-3.980	.000
<b>Delta Hrs</b>	-.560	.576
<b>Reported Hrs</b>	-.855	.393

Figure 32. Large sample test for differences in population means between self-reported tobacco users, and non-users based on independent samples with different variables. From pre-CBT survey, 2003. Cleaned cadets dataset.

	<b>z</b>	<b>Sig.(2-tail)</b>
<b>Time to bed</b>	-2.206	.028
<b>Wake-up time</b>	-2.342	.019
<b>Delta Hrs</b>	-.560	.576
<b>Reported Hrs</b>	-.507	.612

Figure 33. Large sample test for differences in population means between self-reported caffeine users, and non-users based on independent samples with different variables. From pre-CBT survey, 2003. Cleaned cadets dataset.



## APPENDIX D. FALL 2003 DATA

\*calculated using Actiware 3.4, Mini Mitter Co., Inc., Bend, OR 97701

Cadet #	weekend start		weekend end		weekend tot		sch night start		sch night end		sch night tot		combined start		combined end		combined tot	
	mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev
1	1:40	2:01	10:29	3:52	8:19	2:35	1:15	1:26	6:53	2:11	5:17	2:15	1:20	1:20	7:39	2:57	5:56	2:36
2	11:46	2:29	7:46	1:37	6:13	1:12	11:46	1:00	5:30	0:23	5:09	0:43	0:09	1:41	6:15	1:26	5:31	1:01
3	1:23	1:34	8:12	2:22	6:19	2:19	0:22	0:33	5:39	0:24	4:53	0:45	0:43	1:06	6:30	1:49	5:22	1:35
4	3:10	2:06	10:35	2:28	6:39	0:23	0:06	0:44	5:46	0:20	5:03	0:33	0:40	1:33	6:38	2:07	5:21	0:49
5	2:28	1:13	8:09	2:00	5:12	0:51	1:56	0:48	6:19	0:36	4:01	0:49	2:03	0:54	6:45	1:17	4:18	0:57
6	3:38	2:16	9:41	3:27	4:54	2:34	1:37	1:36	6:13	0:19	3:46	1:01	2:19	2:03	7:25	2:35	4:10	1:45
7	1:06	1:04	8:19	1:42	5:55	1:48	0:34	0:51	5:45	0:15	4:22	0:49	0:45	0:57	6:37	1:34	4:53	1:24
8	1:01	0:37	9:31	2:21	7:20	1:31	0:30	0:34	6:01	0:12	4:52	0:32	0:36	0:36	6:45	1:45	5:23	1:17
9	11:29	2:09	7:49	1:39	6:22	1:54	11:29	0:41	6:03	0:53	5:32	0:36	11:40	1:20	6:37	1:26	5:48	1:13
10	10:50	0:13	6:44	1:04	6:34	1:11	10:50	0:47	5:38	0:20	5:51	0:46	10:53	0:43	5:50	0:38	5:59	0:51
11	2:51	1:58	10:39	3:04	6:35	2:16	0:45	0:44	6:08	0:20	4:47	0:38	1:06	1:16	6:53	2:04	5:05	1:13
12	2:16	1:10	10:24	2:55	7:36	2:11	0:39	0:47	5:46	0:20	4:54	0:55	1:09	1:10	7:11	2:41	5:43	1:53
13	1:44	1:35	10:12	2:16	7:13	2:29	0:11	0:42	6:05	0:27	5:02	0:48	0:36	1:12	7:12	2:12	5:38	1:42
14	12:04	0:45	8:41	2:15	7:20	1:57	11:31	0:40	5:59	0:30	5:25	0:51	11:42	0:44	6:49	1:47	6:00	1:33
15	1:16	0:25	8:08	1:32	5:55	1:16	0:26	0:55	5:47	0:26	4:35	0:46	0:34	0:54	6:10	1:07	4:48	0:59
16	2:19	1:55	10:05	2:54	6:22	1:59	1:20	0:41	5:43	0:32	3:47	0:37	1:37	1:12	6:57	2:30	4:30	1:37
17	2:39	1:22	9:11	2:38	5:47	2:22	1:22	1:12	5:37	0:40	3:45	1:11	1:48	1:23	6:48	2:19	4:26	1:54
18	11:38	2:02	8:00	1:32	5:44	1:29	11:38	0:29	5:47	0:23	5:16	0:41	0:12	1:27	6:32	1:24	5:26	1:01
19	3:23	2:24	9:18	2:39	5:25	1:22	1:09	1:23	5:45	1:37	4:12	1:17	1:52	2:02	6:54	2:35	4:36	1:25
20	1:20	2:14	9:14	1:40	7:12	2:15	1:11	1:50	6:03	0:20	4:34	1:39	1:14	1:54	6:56	1:41	5:18	2:09
21	0:41	1:24	8:43	1:40	7:02	1:50	0:30	2:11	6:08	1:22	5:08	1:03	0:34	1:57	6:58	1:54	5:45	1:36
22	11:20	0:37	6:33	1:02	6:14	1:07	11:20	1:00	5:56	0:20	5:39	1:22	11:19	0:57	6:01	0:29	5:44	1:19
23	0:58	1:47	9:01	2:00	7:07	1:41	0:30	0:59	5:54	0:14	4:53	0:52	0:39	1:17	6:54	1:51	5:36	1:35
24	3:22	2:31	9:45	3:27	5:19	2:55	1:19	0:59	6:04	0:25	3:52	0:55	2:02	1:55	7:20	2:40	4:22	1:57
25	2:24	1:11	9:29	2:45	6:25	1:58	1:11	0:49	5:46	0:39	4:14	0:54	1:35	1:06	7:00	2:24	4:58	1:41
26	11:34	1:35	8:29	1:50	7:18	1:43	11:34	0:31	5:55	0:19	5:46	0:30	11:53	1:04	6:47	1:37	6:17	1:17
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28	2:36	6:10	9:46	2:11	9:52	5:13	2:28	3:44	6:39	1:30	5:12	2:41	2:25	4:01	7:24	2:12	6:09	3:51
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33	2:52	1:13	9:27	1:50	5:30	1:22	1:23	1:19	5:31	0:34	3:31	1:14	1:50	1:25	6:41	2:07	4:07	1:32
34	1:28	0:54	9:12	2:05	6:57	2:02	1:03	1:26	5:43	0:24	4:15	1:26	1:19	1:22	6:53	2:03	5:01	2:10
35	1:37	1:30	8:54	1:41	6:19	2:14	1:17	1:05	6:01	0:25	4:16	0:50	1:24	1:14	6:59	1:42	4:57	1:43
36	1:25	1:26	9:13	2:57	7:15	1:51	0:18	0:49	5:53	0:20	5:14	0:46	0:35	1:03	6:41	1:58	5:40	1:23
37	4:42	6:01	10:11	7:02	5:08	4:37	1:08	3:57	5:44	0:30	5:11	2:34	1:29	4:00	6:42	3:13	5:23	2:42
38	2:00	1:29	7:43	1:56	5:11	2:38	0:30	0:54	5:50	0:22	4:48	0:46	1:00	1:19	6:27	1:26	4:56	1:36
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Cadet #	weekend start		weekend end		weekend tot		sch night start		sch night end		sch night tot		combined start		combined end		combined tot	
	mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev	mean	stdev
41	2:43	1:19	10:09	2:59	6:55	2:20	1:03	0:55	6:03	0:16	4:32	0:52	1:35	1:18	7:22	2:33	5:18	1:51
42	1:34	2:20	7:59	1:56	4:52	2:04	0:20	0:40	5:27	0:27	3:58	0:42	0:43	1:30	6:16	1:39	4:15	1:20
43	11:36	0:52	9:38	1:38	7:35	1:50	11:36	0:36	5:38	0:20	5:11	0:29	11:59	0:55	6:47	2:02	5:38	1:39
44	11:51	2:32	9:57	3:18	6:48	1:57	11:51	1:13	5:41	0:19	5:26	1:13	0:40	2:05	6:57	2:38	5:50	1:34
45	11:53	1:29	9:09	2:29	8:27	1:25	11:53	1:17	5:49	0:24	5:28	1:15	11:56	1:20	6:53	2:07	6:26	1:55
46	2:17	2:43	9:26	1:49	6:25	1:46	0:45	0:52	6:31	1:19	5:13	0:58	1:13	1:47	7:25	2:00	5:35	1:22
47	1:31	0:54	8:13	2:09	6:04	1:54	0:44	1:11	5:54	0:26	4:44	1:17	0:59	1:09	6:41	1:40	5:11	1:37
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54	3:03	1:56	12:03	1:04	7:39	0:35	0:22	0:26	6:05	0:24	5:06	0:23	0:37	1:08	6:41	2:04	5:25	0:57
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56	0:57	0:43	8:47	2:30	7:13	1:42	0:02	0:22	6:01	0:19	5:35	0:26	0:18	0:39	6:51	1:51	6:04	1:13
57	11:46	1:24	7:42	2:21	6:36	1:48	11:46	0:31	5:43	0:25	5:33	0:32	0:01	0:57	6:21	1:38	5:53	1:11
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71	11:14	2:05	8:22	2:00	6:32	2:08	11:14	0:21	5:41	0:24	5:54	0:23	11:54	1:33	6:35	1:44	6:07	1:16
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73	11:36	1:56	8:01	1:36	6:03	1:18	11:36	0:29	5:53	0:22	5:37	0:35	0:00	1:14	6:28	1:18	5:44	0:50

## APPENDIX E. CORRELATIONS FOR PRE-CBT SURVEY

Pair of VARs	n	Pearson Correlation	p-value (2-tailed)
Bedtime HS class rank	1257	.112	.000
Wake-up time 1 <sup>st</sup> term military program score	1175	-.069	.017
Whole candidate score (WCS) Wake-up time	1252	-.063	.026
WCS Bedtime	1259	-.111	.000
CEER score Wake-up time	1252	-.059	.036
CEER score Bedtime	1259	-.110	.000
Soda Reported Hrs sleep	1065	-.069	.025
Soda Wake-up time	1080	.080	.008
Soda Bedtime	1083	.067	.027
Coffee Reported Hrs Sleep	857	-.074	.031
Delta Hrs Sleep Coffee	864	-.071	.038

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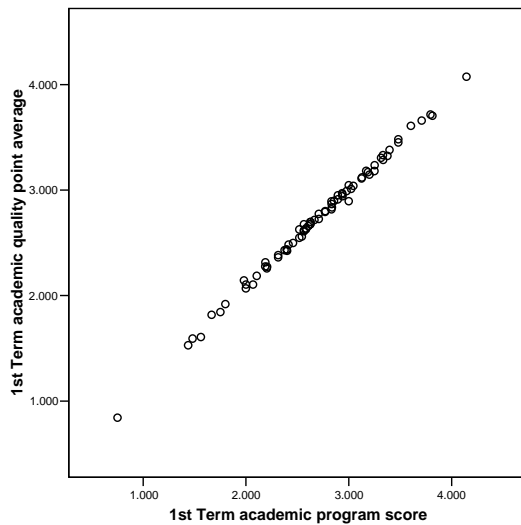
## APPENDIX F. CORRELATIONS FOR PRE-CBT SURVEY: A SUBSAMPLE

Pair of VARs	n	Pearson Correlation	p-value (2-tailed)
Soda Wake-up time	956	.067	.038
Delta Hrs Sleep Coffee	771	-.090	.013
Bedtime CEER score	1107	-1.09	.000
WCS Bedtime	1107	-.106	.000
WCS Wake-up time	1102	-.069	.022
Bedtime HS class rank	1105	.104	.001
Wake-up time 1 <sup>st</sup> term military program score	1038	-.063	.043
CEER score Wake-up time	1102	-.070	.021

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## APPENDIX G. SIGNIFICANT CORRELATIONS FOR FALL DATA

Pair of VARs	n	Pearson Correlation	p-value (2-tailed)
Weekend bedtime 1 <sup>st</sup> term academic QPA	73	-.272	.020
Weekend bedtime 1 <sup>st</sup> term academic program score	73	-.271	.020
Weekend bedtime 1 <sup>st</sup> term academic QPA	69	-.274	.023
Weekend bedtime 1 <sup>st</sup> term academic program score	69	-.273	.023



\*\*\*Note that the 2 measures of academic performance are virtually the same.

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**APPENDIX H. LARGE SAMPLE TESTS FOR DIFFERENCE  
BETWEEN PRE-CBT REPORTED SLEEP AND FALL 2003 SLEEP  
DATA BASED ON PAIRED DATA**

Pairs	Mean (mins)	n	s.d. (mins)	s.e
Delta Sleep	504	64	86	10.8
Weekend Sleep	394		67	8.3
Delta Sleep	504	64	86	10.8
Schoolnight Sleep	293		38	4.7
Delta Sleep	504	64	86	10.8
Overall Sleep	321		37	4.6
Reported Sleep	475	62	77	9.8
Weekend Sleep	397		66	8.3
Reported Sleep	475	62	77	9.8
Schoolnight Sleep	293		36	4.5
Reported Sleep	475	62	77	9.8
Overall Sleep	322		35	4.4

\*\* approximate summary statistics for each pair of variables

				<b>95 % CI of difference</b>			
	<b>Mean</b>	<b>s.d.</b>	<b>s.e.</b>	<b>Lower</b>	<b>Upper</b>	<b>z</b>	<b>Sig.(2-tail)</b>
Delta Sleep Weekend Sleep	110	102	12.8	84.7	135.8	8.622	.000
Delta Sleep Schoolnight Sleep	211	90.1	11.3	188.9	234.2	18.666	.000
Delta Sleep Overall Sleep	184	88.3	11.0	161.6	205.7	16.633	.000
Reported Sleep Weekend Sleep	78	100.0	12.7	52.3	103.1	6.114	.000
Reported Sleep Schoolnight Sleep	182	82.3	10.5	160.8	202.7	17.373	.000
Reported Sleep Overall Sleep	153	81.4	10.3	132.5	173.9	14.815	.000

\*\* paired samples test (time in minutes)

## APPENDIX I: MORNINGNESS-EVENINGNESS & GRADES

**Group Statistics**

Lark_Owl_00011		N	Mean	Std. Deviation	Std. Error Mean
1st Term academic quality point average	Lark	619	2.75787	.628713	.025270
	Owl	557	2.59717	.773784	.032786
1st Term academic program score	Lark	619	2.72527	.661334	.026581
	Owl	557	2.56462	.801600	.033965
1st Term military program score	Lark	619	3.12878	.535831	.021537
	Owl	557	2.94100	.705671	.029900
1st Term physical program score	Lark	619	2.94669	.636255	.025573
	Owl	557	2.82140	.667028	.028263

					95% CI of diff	
	z	Sig.(2-tail)	Mean diff	s.e. diff	Lower	Upper
<b>1<sup>st</sup> term academic QPA</b>	3.882	.000	.160702	.041395	.079478	.241936
<b>1<sup>st</sup> term academic program score</b>	3.725	.000	.160649	.043130	.076021	.245277
<b>1<sup>st</sup> term military program score</b>	5.096	.000	.187777	.036849	.115469	.260085
<b>1<sup>st</sup> term physical program score</b>	3.287	.001	.125288	.038115	.050504	.200071

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## LIST OF REFERENCES

- Acebo, C., Davis, S. S., Herman, K. B., and Carskadon, M. A. (1991). Undergraduate Sleep patterns: evidence of adaptation over time. *Sleep Research*, 20: 111.
- Acebo, C., Sadeh, A., Seifer, R., Tzischinsky, O., Wolfson, A.R., Hafer, A., and Carskadon, M. A. (1999). Estimating sleep patterns with activity monitoring in children and adolescents: how many nights are necessary for reliable measures? *Sleep*, 22(1): 95-103.
- Akerstedt, Torbjorn (1995). Work hours, sleepiness and the underlying mechanisms. *J. Sleep Res*, 4(2): 15-22.
- Belenky, G., Wesensten, N. J., Thorne, D. R., Thomas, M. L., Sing, H. C., Redmond, D. P., et al. (2003). Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: a sleep dose-response study. *Journal of Sleep Research*, 12, 1-12.
- Bonnefond, A., Muzet, A., Winter-Dill, A. S., Bailloeuil, C., Bitouze, F., and Bonneau, A. (2001). Innovative working schedule: introducing one short nap during the night shift. *Ergonomics*, 44(10): 937-45. Abstract from MEDLINE Mar 17, 2004.
- Borbely, A., Baumann, F., Brandeis, D., Strauch, I., and Lehmann, D (1981). Sleep deprivation: effect on sleep stages and EEG power density in man. *Electroencephalography and clinical Neurophysiology*, 51: 483-493.
- Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R., Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Research*, 28(2): 193-213. Abstract from MEDLINE May 20, 2004.
- Carrier, J., and Monk, T. (2000) Circadian rhythms of performance: new trends. *Chronobiology International*, 17(6), 719-732.
- Carskadon, M.A., Acebo, C., Richardson, G.S., Tate, B.A., and Seifer, R. (1997). An approach to studying circadian rhythms of adolescent humans. *J Biol Rhythms*, 12:278-289.
- Carskadon, M.A., Acebo, C., and Seifer, R. (2001). Extended nights, sleep loss, and recovery sleep in adolescents. *Archives Italiennes de Biologie*. 139:3, 301-312.
- Carskadon, M. A., and Davis, S. S. (1989). Sleep-wake patterns in the high-school-to-college transition: preliminary data. *Sleep Research*, 18:113.
- Carskadon M. A., and Dement, W. C. Normal Human Sleep: An Overview. In Kryger, M. H., Roth, T., and Dement, W. C., eds. *Principles and Practice of Sleep Medicine*. Philadelphia; Saunders; 2000.
- Carskadon M. A. (2002) Adolescent Sleep Patterns: Biological, Social, and Psychological Influences. Cambridge University Press.

Carskadon, M. A., Wolfson, A. R., Tzischinsky, O., and Acebo, C. (1995). Early school schedules modify adolescent sleepiness. *Sleep Research*, 24: 92.

Coren, S. *Sleep Thieves: an Eye-Opening Exploration into the Science and Mysteries of Sleep*. New York: Free Press Paperbacks, 1996.

Dement, W.C., and Vaughan, C. *The Promise of Sleep*. New York: Dell Publishing, 1999.

Dinges, D. F., and Kribbs, N. B. (1991). Performing while sleepy: effects of experimentally-induced sleepiness. *Sleep Sleepiness and Performance*. Timothy H. Monk. John Wiley and Sons Ltd: 97-128.

Dinges, D. F., Orne, M. T., Whitehouse, W. G., and Orne, E. C. (1987). Temporal placement of a nap for alertness: contributions of circadian phase and prior wakefulness. *Sleep*, 10(4).

Dinges, D. F., (2004) Critical Research Issues in Development of Biomathematical Models of Fatigue and Performance. *Aviation, Space, and Environmental Medicine*, 75(3) A181-A191.

Eddy, D.R. and Hursh, S. R. (2001). *Fatigue Avoidance Scheduling Tool (FAST)*. AFRL-HE-BR-TR-2001-0140, SBIR Phase I Final Report, Human Effectiveness Directorate Biodynamics and Protection Division, Flight Motion Effects Branch, Brooks AFB, TX 78235-5105.

Fenn, K. M., Nusbaum, H. C., and Margoliash, D. (2003) Consolidation during sleep of perceptual learning of spoken language. *Nature*, 425: 614-616.

Gais, S., Plihal, W., Wagner, U., and Born, J. (2000). Early sleep triggers memory for early visual discrimination skills. *Nature Neuroscience*, 3(12): 1335-1339.

Gau, S. F. and Soong, W. T. (2003). The transition of sleep-wake patterns in early adolescence. *Sleep*, 26(4): 449-54.

Giannotti, F., and Cortesi, F. Sleep patterns and daytime function in adolescence: an epidemiological survey of an Italian high school student sample. Edited by Carskadon, M. *Adolescent Sleep Patterns: Biological, Social, and Psychological Influences*, 2002.

Gillin, J. C., Drummond, S. P. A. Medication and Substance. In Kryger, MH, Roth T, Dement WC, eds. *Principles and Practice of Sleep Medicine*. Philadelphia; Saunders; 2000.

Harrison, Y. and Horne, J. (2000). The impact of sleep deprivation on decision making: a review. *Journal of Experimental Psychology: Applied*, 6(3): 236-49.

Horne, J. A. and Ostberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *Int J Chronobiol*, 4(2): 97-110.

Horne, J.A. (1993) Human sleep, sleep loss, and behaviour: implications for the prefrontal cortex and psychiatric disorder. *British Journal of Psychiatry*, 162: 413-419.

Horne, James A. (1998) *Why We Sleep: the Functions of Sleep in Humans and Other Mammals* Oxford: Oxford University Press.

Johnson, Laverne C. (1982). Sleep Deprivation and Performance. *Biological Rhythms, Sleep, and Performance*, Edited by Wilse B. Webb., 111-141.

Karni, A., Tanne, D., Rubenstein, B. S., Askenasy, J. J. M., and Sagi, D. (1994). Dependence on REM sleep of overnight improvement of a perceptual skill. *Science*, 265 (5172): 679-682.

Kitay, J. I. (1954). Pineal lesions and precocious puberty: A review. *Journal of Clinical Endocrinology and Metabolism*, 14: 622-625.

Krueger, J. M., Fang, J. Host Defense: In Kryger, MH, Roth T, Dement WC, eds. *Principles and Practice of Sleep Medicine*. Philadelphia; Saunders; 2000.

Laberge, L., Carrier, J., Lesperance, P., Lambert, C., Vitaro, F., Tremblay, R. E., and Montplaisi, J. (2000) Sleep and circadian phase characteristics of adolescent and young adult males in a naturalistic summertime condition. *Chronobiol Int*, 17(4): 489-501

Leger, D. (1994). The cost of sleep-related accidents: a report for the national commission on sleep disorders research. *Sleep*, 17(1): 84-93.

Lieberman, H. R., Tharion, W. J., Shukitt-Hale, B., Speckman, K. L., Tulley, R. (2002) Effects of caffeine, sleep loss, and stress on cognitive performance and mood during U.S. Navy SEAL training. *Psychopharmacology*, 164:250-261.

Lumley, M., Roehrs, T., Zorick, F., Lamphere, J., and Roth, T. (1986). The alerting effects of naps in sleep-deprived subjects. *Psychophysiology*, 11, 133-46.

Miller, N.L., Balduus, B.R., Coard, H.F., Sanchez, S., and Redmond, D.R., "Timing of the Major Sleep Period as a Fatigue Countermeasure in U.S. Navy Recruits," Proceedings of the Aerospace Medical Association, May 2003.

Mitler, M. M., Carskadon, M. A., Czeisler, C. A., Dement, W. C., Dinges, D. F., Graeber, R. C. (1988). Catastrophes, sleep and public policy: Consensus report. *Sleep*, 11:100-109.

Monk, T. H. (1990). The relationship of chronobiology to sleep schedules and performance demands. *Work and Stress*, 4(3): 227-236.

Naitoh, P., Kelly, T., and Babkoff, H. (1991). Sleep inertia: Is there a worst time to wake up? Naval Health Research Center Technical Report 91-45, San Diego.

Naitoh, P., Kelly, T., and Englund, C. (1989). Health Effects of Sleep Deprivation. Naval Health Research Center Technical Report 89-46, San Diego.

Naitoh, P., and Angus, R.G. (1987). Napping and Human Functioning during Prolonged work. Naval Health Research Center Technical Rep 87-21. Naval Health Research Center, San Diego.

Roberts, R. D., Irvine, S. (1999). Construction and validation of the lark-owl (chronotype) indicator (loci): status report. Technical report. Manuscript in preparation, <http://www.psych.usyd.edu.au/difference5/papers/locistatus.html>.

Rosekind, M. R., Graeber, R. C., Dinges, D. F., Connell, L. J., Rountree, M. S., Spinweber C. L., Gillen, K. A. (1994). Crew Factors in Flight Operations IX: Effects of Planned Cockpit rest on Crew Performance and Alertness in Long Haul Operations

(NASA Technical Memorandum 108839). Moffett Field, California: NASA Ames Research Center.

Sadeh, Avi, and Acebo, C. (2002). The role of actigraphy in sleep medicine. *Sleep Medicine Reviews*, 6: 113-124.

Sadeh, A., Hauri, P. J., Kripke, D. F., and Lavie, P. (1995). The role of actigraphy in the evaluation of sleep disorders. *Sleep*, 18(2): 288-302.

Shay, J. (1998). Ethical Standing for Commander Self-Care: The Need for Sleep. Army War College. *Parameters*, 93-105.

Stepanski, E. J. Behavioral Therapy for Insomnia. In Kryger, MH, Roth T, Dement WC, eds. *Principles and Practice of Sleep Medicine*. Philadelphia; Saunders; 2000.

Stickgold, R., James, L., and Hobson, J. A. (2000) Visual discrimination learning requires sleep after training. *Nature Neuroscience*, 3(12):1237-8.

Taillard, J., Philip, P., Chastang, J. F., and Bioulac, B. (2004). Validation of Horne and Ostberg morningness-eveningness questionnaire in a middle-aged population of French workers. *J Biol Rhythms*, 19(1): 76-86.

Takahashi, M., Arito, H., and Fukuda, H. (1999). Nurses' workload associated with 16-h night shifts. II: Effects of a nap taken during the shifts. *Psychiatry Clin Neurosci*, 53(2):223-5. Abstract obtained from Medline. March 11, 2004.

Trockel, M. T., Barnes, M. D., and Egget, D. L. (2000). Health-related variables and academic performance among first year college students: implications for sleep and other behaviors. *Journal of American college health*, 49: 125-31.

Wahlstrom, K. L. Accommodating the sleep patterns of adolescents within current educational structures: an uncharted path. Edited by Carskadon, M. *Adolescent Sleep Patterns: Biological, Social, and Psychological Influences*, 2002.

Waldhauser, F., Steger, H. (1986). Changes in melatonin secretion with age and pubescence. *Journal of Neural Transmission. Supplementum*,. 21: 183-197.

Walker, M. P., Brakefield, T., Hobson, J.A., and Stickgold, R. (2003). Dissociable stages of human memory consolidation and reconsolidation. *Nature*. 425: 616-620.

Wilson, M. A., and McNaughton, B. L. (1994) Reactivation of hippocampal ensemble memories during sleep. *Science*, 265 (5172): 676-679.

Wyatt, J. K., Bootzin, R. R., Anthony, J., and Stevenson, S. (1992). Does sleep onset produce retrograde amnesia? *Sleep Research*, 21: 113.

Wright, K. P., Hull, J. T., and Czeisler, C. A., (2002). Relationship between alertness, performance, and body temperature in humans. *American Journal Physiol Regul Integr Comp Physiol*, 283(6): R1370-7.

Van Dongen, H. P. A., Maislin, G., Mullington, J. M., and Dinges, D. F. (2003). The Cumulative Cost of Additional Wakefulness: Dose-response effects on Neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep*, 26, 2.



Van Dongen, H. P. A., and Dinges, D. F. Circadian rhythms in fatigue, alertness, and performance. In Kryger, MH, Roth T, Dement WC, eds. *Principles and Practice of Sleep Medicine*. Philadelphia; Saunders; 2000.

Van Dongen, H. P. A., Rogers, N. L., and Dinges, D. F., (2003) Sleep debt: Theoretical and empirical issues. *Sleep and Biological Rhythms* 1: 5-13.

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## BIBLIOGRAPHY

Acebo, C., Davis, S. S., Herman, K. B., and Carskadon, M. A. (1991). Undergraduate Sleep patterns: evidence of adaptation over time. *Sleep Research*, 20: 111.

Acebo, C., Sadeh, A., Seifer, R., Tzischinsky, O., Wolfson, A.R., Hafer, A., and Carskadon, M. A. (1999). Estimating sleep patterns with activity monitoring in children and adolescents: how many nights are necessary for reliable measures? *Sleep*, 22(1): 95-103.

Akerstedt, Torbjorn (1995). Work hours, sleepiness and the underlying mechanisms. *J. Sleep Res*, 4(2): 15-22.

Belenky, G., Wesensten, N. J., Thorne, D. R., Thomas, M. L., Sing, H. C., Redmond, D. P., et al. (2003). Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: a sleep dose-response study. *Journal of Sleep Research*, 12, 1-12.

Belenky, G., Balkin, T. J., Redmond, D. P., Sing, H. C., Thomas, M. L., Thorne, D. R., et al. (1996). Sustained Performance During Continuous Operations: The U.S. Army's Sleep Management System. Paper presented at the 1996 Army Science Conference.

Bonnefond, A., Muzet, A., Winter-Dill, A. S., Bailloeuil, C., Bitouze, F., and Bonneau, A. (2001). Innovative working schedule: introducing one short nap during the night shift. *Ergonomics*, 44(10): 937-45. Abstract from MEDLINE Mar 17, 2004.

Borbely, A., Baumann, F., Brandeis, D., Strauch, I., and Lehmann, D (1981). Sleep deprivation: effect on sleep stages and EEG power density in man. *Electroencephalography and clinical Neurophysiology*, 51: 483-493.

Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R., Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Research*, 28(2): 193-213. Abstract from MEDLINE May 20, 2004.

Carrier, J., and Monk, T. (2000) Circadian rhythms of performance: new trends. *Chronobiology International*, 17(6), 719-732.

Carskadon, M.A., Acebo, C., Richardson, G.S., Tate, B.A., and Seifer, R. (1997). An approach to studying circadian rhythms of adolescent humans. *J Biol Rhythms*, 12:278-289.

Carskadon, M.A., Acebo, C., and Seifer, R. (2001). Extended nights, sleep loss, and recovery sleep in adolescents. *Archives Italiennes de Biologie*. 139:3, 301-312.

Carskadon, M. A., and Davis, S. S. (1989). Sleep-wake patterns in the high-school-to-college transition: preliminary data. *Sleep Research*, 18:113.

Carskadon M. A., and Dement, W. C. Normal Human Sleep: An Overview. In Kryger, M. H., Roth, T., and Dement, W. C., eds. *Principles and Practice of Sleep Medicine*. Philadelphia; Saunders; 2000.

Carskadon M. A. (2002) *Adolescent Sleep Patterns: Biological, Social, and Psychological Influences*. Cambridge University Press.

Carskadon, M. A., Wolfson, A. R., Tzischinsky, O., and Acebo, C. (1995). Early school schedules modify adolescent sleepiness. *Sleep Research*, 24: 92.

Coren, S. *Sleep Thieves: an Eye-Opening Exploration into the Science and Mysteries of Sleep*. New York: Free Press Paperbacks, 1996.

Dement, W.C., and Vaughan, C. *The Promise of Sleep*. New York: Dell Publishing, 1999.

Devore, Jay. (2000) *Probability and Statistics: For Engineering and the Sciences*. 5<sup>th</sup> Edition. Thomson Learning. Duxbury.

Dinges, D. F., and Kribbs, N. B. (1991). Performing while sleepy: effects of experimentally-induced sleepiness. *Sleep Sleepiness and Performance*. Timothy H. Monk. John Wiley and Sons Ltd: 97-128.

Dinges, D. F., Orne, M. T., Whitehouse, W. G., and Orne, E. C. Temporal placement of a nap for alertness: contributions of circadian phase and prior wakefulness. *Sleep*, Vol 10, No. 4, 1987.

Dinges, D. F., (2004) Critical Research Issues in Development of Biomathematical Models of Fatigue and Performance. *Aviation, Space, and Environmental Medicine*, 75(3) A181-A191.

Eddy, D.R. and Hursh, S. R. (2001). *Fatigue Avoidance Scheduling Tool (FAST)*. AFRL-HE-BR-TR-2001-0140, SBIR Phase I Final Report, Human Effectiveness Directorate Biodynamics and Protection Division, Flight Motion Effects Branch, Brooks AFB, TX 78235-5105.

Fenn, K. M., Nusbaum, H. C., and Margoliash, D. (2003) Consolidation during sleep of perceptual learning of spoken language. *Nature*, 425: 614-616.

Gais, S., Plihal, W., Wagner, U., and Born, J. (2000). Early sleep triggers memory for early visual discrimination skills. *Nature Neuroscience*, 3(12): 1335-1339.

Gau, S. F. and Soong, W. T. (2003). The transition of sleep-wake patterns in early adolescence. *Sleep*, 26(4): 449-54.

Giannotti, F., and Cortesi, F. Sleep patterns and daytime function in adolescence: an epidemiological survey of an Italian high school student sample. Edited by Carskadon, M. *Adolescent Sleep Patterns: Biological, Social, and Psychological Influences*, 2002.

Gillin, J. C., Drummond, S. P. A. Medication and Substance. In Kryger, MH, Roth T, Dement WC, eds. *Principles and Practice of Sleep Medicine*. Philadelphia; Saunders; 2000.

Harrison, Y. and Horne, J. (2000). The impact of sleep deprivation on decision making: a review. *Journal of Experimental Psychology: Applied*, 6(3): 236-49.

Horne, J. A. and Ostberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *Int J Chronobiol*, 4(2): 97-110.

Horne, J. A. (1993) Human sleep, sleep loss, and behaviour: implications for the prefrontal cortex and psychiatric disorder. *British Journal of Psychiatry*, 162: 413-419.

Horne, J. A. (1998) *Why We Sleep: the Functions of Sleep in Humans and Other Mammals* Oxford: Oxford University Press.

Hursh, S.R., et al. (2004) Fatigue models for applied research in warfighting. *Aviation, Space, and Environmental Medicine*, 75(3): A44-60.

Johnson, Laverne C. (1982). Sleep Deprivation and Performance. *Biological Rhythms, Sleep, and Performance*, Edited by Wilse B. Webb., 111-141.

Karni, A., Tanne, D., Rubenstein, B. S., Askenasy, J. J. M., and Sagi, D. (1994). Dependence on REM sleep of overnight improvement of a perceptual skill. *Science*, 265 (5172): 679-682.

Kimeldorf, G, Sampson, A. R., Whitaker, L. R. (1992). Min and max scorings for two-sample ordinal data. *Journal of the American Statistical Association*, 87(417): 240-247.

Kitay, J. I. (1954). Pineal lesions and precocious puberty: A review. *Journal of Clinical Endocrinology and Metabolism*, 14: 622-625.

Krueger, J. M., Fang, J. Host Defense: In Kryger, MH, Roth T, Dement WC, eds. *Principles and Practice of Sleep Medicine*. Philadelphia; Saunders; 2000.

Laberge, L., Carrier, J., Lesperance, P., Lambert, C., Vitaro, F., Tremblay, R. E., and Montplaisi, J. (2000) Sleep and circadian phase characteristics of adolescent and young adult males in a naturalistic summertime condition. *Chronobiol Int*, 17(4): 489-501

Leger, D. (1994). The cost of sleep-related accidents: a report for the national commission on sleep disorders research. *Sleep*, 17(1):84-93.

Lieberman, H. R., Tharion, W. J., Shukitt-Hale, B., Speckman, K. L., Tulley, R. (2002) Effects of caffeine, sleep loss, and stress on cognitive performance and mood during U.S. Navy SEAL training. *Psychopharmacology*, 164:250-261.

Lumley, M., Roehers, T., Zorick, F., Lamphere, J., and Roth, T. (1986). The alerting effects of naps in sleep-deprived subjects. *Psychophysiology*, 11, 133-46.

Miller, N.L., Baldus, B.R., Coard, H.F., Sanchez, S., and Redmond, D.R., "Timing of the Major Sleep Period as a Fatigue Countermeasure in U.S. Navy Recruits," Proceedings of the Aerospace Medical Association, May 2003.

Mitler, M. M., Carskadon, M. A. , Czeisler, C. A., Dement, W. C., Dinges, D. F., Graeber, R. C. (1988). Catastrophes, sleep and public policy: Consensus report. *Sleep*, 11:100-109.

Monk, T. H. (1990). The relationship of chronobiology to sleep schedules and performance demands. *Work and Stress*, 4(3): 227-236.

Montgomery, D. C. *Introduction to Linear Regression Analysis*. 3<sup>rd</sup> Edition. John Wiley and Sons, Inc. New York, 2001.

Naitoh, P., Kelly, T., and Babkoff, H. (1991). Sleep inertia: Is there a worst time to wake up? Naval Health Research Center Technical Report 91-45, San Diego.

Naitoh, P, Kelly, T., and Englund, C. (1989). Health Effects of Sleep Deprivation. Naval Health Research Center Technical Report 89-46, San Diego.

Naitoh, P., Englund, C.E., and Ryman, D.H. (1986). Sleep Management in sustained operations: User's guide. Naval Health Research Center Technical Rep 86-22. Naval Health Research Center, San Diego.

Naitoh, P., and Angus, R.G. Napping and Human Functioning during Prolonged work. Naval Health Research Center Technical Rep 87-21. Naval Health Research Center, San Diego.

Roberts, R. D., Ivine, S. (1999). Construction and validation of the lark-owl (chronotype) indicator (loci): status report. Technical report. Manuscript in preparation, <http://www.psych.usyd.edu.au/difference5/papers/locistatus.html>.

Rosekind, M. R., Graeber, R. C., Dinges, D. F., Connell, L. J., Rountree, M. S., Spinweber C. L., Gillen, K. A. (1994). Crew Factors in Flight Operations IX: Effects of Planned Cockpit rest on Crew Performance and Alertness in Long Haul Operations (NASA Technical Memorandum 108839). Moffett Field, California: NASA Ames Research Center.

Sadeh, Avi, and Acebo, C. (2002). The role of actigraphy in sleep medicine. *Sleep Medicine Reviews*, 6: 113-124.

Sadeh, A., Hauri, P. J., Kripke, D. F., and Lavie, P. (1995). The role of actigraphy in the evaluation of sleep disorders. *Sleep*, 18(2): 288-302.

Shay, J. (1998). Ethical Standing for Commander Self-Care: The Need for Sleep. Army War College. *Parameters*, 93-105.

Schein, E. H. (1957), The effects of sleep deprivation on performance in a simulated communications task. *Journal of Applied Psychology*, 41(4).

Stepanski, E. J. Behavioral Therapy for Insomnia. In Kryger, MH, Roth T, Dement WC, eds. *Principles and Practice of Sleep Medicine*. Philadelphia; Saunders; 2000.

Stickgold, R., James, L., and Hobson, J. A. (2000) Visual discrimination learning requires sleep after training. *Nature Neuroscience*, 3(12):1237-8.

Taillard, J., Philip, P., Chastang, J. F., and Bioulac, B. (2004). Validation of Horne and Ostberg morningness-eveningness questionnaire in a middle-aged population of French workers. *J Biol Rhythms*, 19(1): 76-86.

Takahashi, M., Arito, H., and Fukuda, H. (1999). Nurses' workload associated with 16-h night shifts. II: Effects of a nap taken during the shifts. *Psychiatry Clin Neurosci*, 53(2):223-5. Abstract obtained from Medline. March 11, 2004.

Trockel, M. T., Barnes, M. D., and Egget, D. L. (2000). Health-related variables and academic performance among first year college students: implications for sleep and other behaviors. *Journal of American college health*, 49: 125-31.

Wahlstrom, K. L. Accommodating the sleep patterns of adolescents within current educational structures: an uncharted path. Edited by Carskadon, M. *Adolescent Sleep Patterns: Biological, Social, and Psychological Influences*, 2002.

Waldhauser, F., Steger, H. (1986). Changes in melatonin secretion with age and pubescence. *Journal of Neural Transmission. Supplementum*,. 21: 183-197.

Walker, M. P., Brakefield, T., Hobson, J.A., and Stickgold, R. (2003). Dissociable stages of human memory consolidation and reconsolidation. *Nature*. 425: 616-620.

Williamson, A. M., Feyer, A., Mattick, R. P., Friswell, R., and Finlay-Brown, S. (2001) Developing measures of fatigue using an alcohol comparison to validate the effects of fatigue on performance. Accident Analysis and prevention. [www.elsevier.com/locate/aap](http://www.elsevier.com/locate/aap)

Williamson, A. M., and Feyer, A. M. (2001) Does sleep deprivation impair cognitive and motor performance as much as alcohol intoxication? *Western Journal of Medicine*. San Francisco. 174: 180-181.

Wilson, M. A., and McNaughton, B. L. (1994) Reactivation of hippocampal ensemble memories during sleep. *Science*, 265 (5172): 676-679.

Wyatt, J. K., Bootzin, R. R., Anthony, J., and Stevenson, S. (1992). Does sleep onset produce retrograde amnesia? *Sleep Research*, 21: 113.

Wright, K. P., Hull, J. T., Czeisler, C. A., (2002). Relationship between alertness, performance, and body temperature in humans. *American Journal Physiol Regul Integr Comp Physiol*, 283(6): R1370-7.

Van Dongen, H. P. A., Maislin, G., Mullington, J. M., and Dinges, D. F. (2003). The Cumulative Cost of Additional Wakefulness: Dose-response effects on Neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep*, 26, 2.

Van Dongen, H. P. A., and Dinges, D. F. Circadian rhythms in fatigue, alertness, and performance. In Kryger, MH, Roth T, Dement WC, eds. *Principles and Practice of Sleep Medicine*. Philadelphia; Saunders; 2000.

Van Dongen, H. P. A., Rogers, N. L., and Dinges, D. F., (2003) Sleep debt: Theoretical and empirical issues. *Sleep and Biological Rhythms* 1: 5-13.

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